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Citizen Science with Resource-poor Farmers as a new Approach to Climate Adaptation and Food Security: Evidence from Honduras

M.Sc. thesis

Integrated Natural Resource Management

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Abstract

Smallholder farmers in developing countries are among the most vulnerable population to the adverse effects of climate change (Jones & Thornton 2003, Morton 2007), and adaptations of farming system practices to changing conditions are necessary in order to preserve food security of farming households. Adjusting the choice of crop varieties is a highly effective adaptation strategy (Rosenzweig & Tubiello 2007), but farmers often lack access to existing varietal diversity. Stationary plant breeding and generic distribution of improved varieties often failed to meet farmers' highly location-specific environmental conditions and socio-cultural needs (Ashby 2009, Vernooy 2009). Participatory methodologies like participatory variety selection (PVS) address these problems, but bear various methodological pitfalls, leading to low adoption rates of new varieties, and are not scalable (Misiko 2013). Modern communication technologies and recent experiences in citizen science (Hand 2010, Dickinson et al. 2012) open new options for upscaling PVS. In Crowdsourcing Crop Improvement (CCI), farmers cultivate experimental quantities of three crop varieties, and feedback simple observations to researchers via triadic comparisons (Martin 2004, van Etten 2011). Experimentation takes place on farmers' own plots, requirements for local group organisation are low, and data collection via mobile telephones allows massive upscaling. This way, farmers are exposed to varietal diversity and are enabled to identify adaption solutions. By fitting Bradley-Terry models (Bradley & Terry 1952, Strobl et al. 2011) to farmers' observations, researchers possess a tool to evaluate germplasm in a rapid and cost-effective way, in multiple, diverse environments.

This study contributes to the development and improvement of the CCI methodology by providing evidence on open questions from a CCI project with common bean in Honduras, and deriving recommendations for methodological adaptations. Five topics were studied: The selection of crop traits (and thus, the research agenda setting) by extensionists and researchers; the accuracy of farmers' observations as a research tool;

questions of gender equity; participants' motivation and effective incentives; possible strategies for upscaling the local experiences.

By focus group discussions and semi-structured interviews with participants, as well as by econometric choice games, it is shown that extensionists and researchers had made an appropriate selection of evaluative criteria for farmers in all four research regions and that the specific questions addressed in CCI are relevant for smallholders.

CCI is a research methodology, usable for the evaluation of germplasm in variety release procedures. The accuracy of farmers' observations on four pre-harvest criteria in CCI trials was assessed experimentally. Accuracy depends on the ease of visual observability of the respective crop attribute, and allows significant distinction of varieties by using Bradley-Terry models. Farmers' observations are not random, and 77-100 percent of the observations on the four traits are fully or nearly fully valid.

By focus group discussions with women farmers and key informant interviews with extensionists from the NGOs implementing the methodology, it is shown that CCI fosters gender equity in rural communities due to the empowerment of women, primarily by building agronomic capacity.

Participants' motivation was studied using semi-structured interviews and focus group discussions. The motivation of farmers to participate is driven by rational motives. Farmers seek improved livelihoods and food security, and perceive CCI as a promising strategy to this end. They are primarily incentivised by agronomic capacity building, access to improved varieties, and the generation of social capital. Smallholder farmers may be incentivised to participate by the generation of social and human capital in training events.

In a focus group discussion with farmers, key informant interviews with extensionists, as well as direct observation of CCI trials and farmers' observation, two kinds of methodological obstacles to upscaling were identified. Massive upscaling of CCI in independence from existing local group structures requires overcoming two types of methodological obstacles: Firstly, requirements of individual facilitation need to be decreased by simplifying the process for participants and using mobile telephone infrastructure for data collection and information feedback. Secondly, CCI needs to emancipate from existing local groups, by incentivising and training 'local facilitators' as CCI outreach staff in rural communities.

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Tables presenting research findings are shaded.

Illustrative tables or tables presenting methods are white.

Abbreviations

Bioversity	*Bioversity International*, the operating name of the International Plant Genetic Resources Institute (IPGRI) and the International Network for Improvement of Banana and Plantain (INIBAP)
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CCI	Crowdsourcing Crop Improvement
CGIAR	Consultative Group for International Agricultural Research
CIAL	*Comité de Investigación Agrícola Local*, Local Agricultural Research Committee
FIPAH	*Fundación para la Investigación Participativa con Agricultores de Honduras*: Foundation for Participatory Research with Farmers in Honduras, NGO devoted to farmer participatory research based in La Ceiba.
n	Number of respondents
PIF	*Programa de Investigaciones en Frijol*: Common Bean Research Program at Zamorano Panamerican Agricultural College, a private college for agricultural careers.
PPB	Participatory Plant Breeding
PRR	*Programa de Reconstrucción Rural*: Rural Reconstruction Program, an NGO based in the Yojoa Lake area devoted to rural development in Honduras.
PVS	Participatory Variety Selection
R	R programming language and environment, see www.r-project.org
SD	Standard deviation
Wageningen UR	Wageningen University and Research Centre (WUR), a public university in Wageningen, Netherlands. It was collaborated with PhD candidate Eskender Beza of WUR for the research about farmers' motivation to participate in citizen science, and the potential of using mobile phone technologies.

Zamorano	*Escuela Agrícola Panamericana (Zamorano)*: The Zamorano Panamerican Agricultural School, a private college for agricultural careers.

1 Introduction

1.1 Problem statement

Subsistence farmers in developing countries, often farming small holdings with minimal input use in marginal environments and relying entirely on rainfall for irrigation, may be among the most vulnerable population to the effects of climate change (Jones & Thornton 2003, Morton 2007, FAO 2008). The next decades are expected to bring an increasingly variable climate and more extreme weather events to many regions characterised by resource-poor subsistence farming, particularly dry spells and periods of excessive rain (IPCC 2013). Changing climate may also mean shifting pest and disease vector ranges (Rosenzweig et al. 2001) and shorter growing seasons (IPCC 2013). Generally, a trend towards declining yields of major staple crops is expected (Jones & Thornton 2003, Wheeler & von Braun 2013, Challinor et al. 2014).

Climate change puts smallholders, adapted to their specific environment, under adaptation pressure, as it may entail shifts in the suitability ranges of crops and crop varieties. For instance, optimum ranges of low altitude, drought-tolerant, bean varieties may be expected to move higher up, and local varieties may not be prepared for previously uncommon biological stressors.

Many authors have emphasised that smallholders adapt to climate change by making smart use of agricultural biodiversity, or that making the latter available is a key strategy to enable farmers to cope with changing conditions (Lane & Jarvis 2007, Altieri & Koohafkan 2008, Di Falco et al. 2010, Meldrum et al. 2013). Challinor et al. (2014) provide evidence that variety adjustment is the most effective agronomic strategy to maintain yields under changing climate. Farmers will need new varieties in order to maintain current yield levels under changing pressures, and these may not necessarily need to be newly bred. Promising planting material can be identified in areas that experienced similar climate and disease regimes previously. Yet, given the strong heterogeneity of smallholder agricultural environments within countries or regions, along with highly regional preferences in terms of grain colour or taste, any one-size-fits-all solution is unlikely to work.

Despite the existence and conservation of a large range of agricultural biodiversity in genebanks, including the most appropriate adaptation option, it is not usually available to smallholder farmers, due to the absence of seed market networks. Crop variety researchers at agricultural R&D organisations often find it hard to disseminate new crosses, and thus adoption of improved varieties is often limited to areas nearby the research facilities (Yirga et al. 1996). Furthermore, testing new varieties involves the risk of failure, which further hinders adaptation by risk-averse subsistence farmers. In response, a methodology is needed that facilitates access to a broad variety of agricultural biodiversity, and encourages small-scale experimentation with minimum risk.

Participatory approaches, like participatory variety selection (PVS), have been developed and implemented for the identification and adoption of suitable germplasm by farmers (Vernooy 2003, Ceccarelli et al. 2009). Yet, these methodologies' coverages are commonly bound by requirements of group organisation, facilitation by a research organisation, and relatively small participant numbers. Furthermore, deductive cleavages between observations on PVS plots and the realities of subsistence plots persist, like labour constraints or differing soil conditions. Such cleavages restrict adoption and field sustainability of varieties selected by PVS (Misiko 2013). By using modern communication technologies and building on recent experiences in maximally decentralised citizen science (Silvertown 2009, Dickinson & Bonney 2012), a methodology for the dissemination and selection of germplasm on farmers' own plots can be developed. This study contributes to the development of such a methodology.

1.2 Antecendents

Bioversity International, the working name of the International Plant Genetic Resources Institute (IPGRI) and the International Network for the Improvement of Banana and Plantain (INIBAP), is an international research-for-development organisation. Bioversity provides scientific evidence and management practices to decision-makers worldwide, with the aim of nourishing humanity in a sustainable way, by making use of agricultural biodiversity. The introduction of Crowdsourcing Crop Improvement is part of the *Seeds for Needs* campaign, including over 20,000 smallholder farmers in 11 countries[1]. *Seeds for Needs* is carried out by various partner organisations within the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)[2].

With a changing climate, vulnerable and affected farmers need to adapt to new conditions in order to maintain livelihoods and, more precisely, food security from family farming.

[1] http://www.bioversityinternational.org/seeds-for-needs/
[2] For more information, visit: http://ccafs.cgiar.org/

The two concepts, climate adaptation and food security, are tightly linked, the pursuit of food security being a key driver for up-taking adaptation measures. Household-level food security has been defined to include the ability of a (farming) household to provide adequate acquisition and allocation of nutrition to all its members (Pinstrup-Andersen 2009). Permanent food security implies the *ability*, not the realisation, of sufficient access to adequate food, since trade-offs in the allocation of household income are family specific, potentially favouring e.g. schooling fees over nutrition. Specifically, it may mean the ability of a family farm to reliably generate sufficient income and resist climatic variability and shocks. Climate adaptation as defined by Adger et al. (2005) is a large set of adjustments of individual or collective behaviour and policy, both in reaction to observed climate change and in anticipation of expected future changes, and at different spatial and temporal scales, *"in order to alleviate adverse impacts of change or take advantage of new opportunities."* In the sense of this study, climate adaptation will refer to farmers adopting new technologies.

One key tennet this study is grounded on was explained before: Smallholder farmers in the global south are particularly affected by climate change, and are required to adopt adaptation measures in order to compensate with negative climate impacts, i.e. in order to maintain current livelihoods and food security. As was shown, exploiting agricultural biodiversity and adjusting crop variety choice can be a highly effective strategy to this end (Challinor et al. 2014). However, in a strongly variable social-ecological system, solutions to climate adaptation must be context specific. This study presents and examines *Crowdsourcing Crop Improvement*, proposed by Bioversity's Jacob van Etten (2011) - a system of participatory research in which smallholder farmers are enabled to identify the most useful variety solution to them, among a larger set of options. The shortcomings of conventional and 'traditional' participatory variety research approaches are outlined, and the methodology's potential as a research method and a powerful adaptation measure are highlighted.

The introduction of CCI in Honduras has benefitted strongly from almost two decades of participatory agricultural research by local agricultural research committees (Ashby et al. 1995, Classen et al. 2005, CIALs for their Spanish acronym). In CIALs, farmers, usually from one single community, join to perform agricultural experimentation together as a formal group (Classen et al. 2005), and both PVS and PPB, primarily for the staple crops maize and beans, are important activities. CIALs are rural grass-root, but formal organisations, whose creation is fostered by rural NGOs. In Honduras, these groups cooperate e.g. with the Common Bean Research Program of an agricultural research organisation, have evaluated germplasm in PVS and PPB procedures, and have contributed to variety release (Rosas 2001, Reyes 2011). Hence, before CCI was introduced into the research area, substantial social, human and institutional capital established a favourable environment for upscaling a participatory research methodology - from collective CIAL work on shared plots, to even more decentral individual experiments in CCI. Many CIAL members already possessed a sometimes profound notion of research, knowledge about crops and selection of varieties, as well as a sense of commitment to their communities (Humphries et al. 2000, Rosas et al. 2003).

1.3 Theoretic approach

1.3.1 Relevance of agricultural biodiversity

Over the last decades, national and international crop research has unquestionably led to substantial increases in yields and environmental stability of many crop species. However, simultaneously, a sharp drop in agricultural diversity has been observed (Thrupp 2000, Heal et al. 2004). Today, the world's nutrition largely depends on few increasingly homogeneous varieties of merely a dozen crops (Vernooy 2003). The number of crop varieties in use has fallen drastically since the rise of high-yielding varieties (HYVs) in the 1960s and 1970s, developed and promoted both by national agricultural research institutes and international bodies like the FAO (Thrupp 2000). In some cases, like in Sri Lanka, over 95% of rice landraces have been lost (Thrupp 2000). While improved varieties have increased farm productivity in many, but not all places, the agricultural sector has become more vulnerable to pathogens (Heal et al. 2004) and climatic changes (Rosenzweig et al. 2001) with increasing genetic uniformity. Farm- and landscape-level crop and variety diversity have been pointed out as crucial assets for encountering current and future challenges of climate change and food supply, both in small and large-scale holdings (Thrupp 2000, Rosenzweig et al. 2001, Heal et al. 2004, Lane & Jarvis 2007, DiFalco et al. 2010).

1.3.2 Participatory Plant Breeding and Participatory Variety Selection

Until today, crop improvement and variety development is largely carried out by centralised, national or international research centres (Vernooy et al. 2009). After the "Green revolution" of the 1960s and 1970s, when the introduction of high-yielding varieties (HYVs) caused massive yield increases in many agricultural areas worldwide, it was soon acknowledged that these often display their full potential only under high-input conditions, and the lack of access to inputs like irrigation, fertiliser, or agrochemicals has limited any production increases in many smallholder systems (Wannitikul 1997, Thrupp 2000). In response, since the early 1990s, a paradigm shift towards participatory approaches has started taking place among researchers and plant breeders worldwide: "*It is now widely accepted that an alternative approach, less dependent on external inputs and able to cope with ecological uncertainty and diversity, is required for poor people farming in low-potential areas*" (Okali et al. 1994). Participatory Plant Breeding (PPB), involving farmers and their life-long expertise, and taking into account the real conditions and constraints of smallholder farms, is now a common, yet niche practice in many developing countries (Vernooy 2003, Ceccarelli & Grando 2007).

While it seems intuitive that including farmers in the process of crop improvement may yield more effective outcomes, the degree of this involvement can vary strongly: Participation may range from *contractual* (farmers provide land and/or service, but have no decision-making power), to *consultative* (farmers are consulted for information, e.g. on their constraints, but decisions are made by researchers in a patient-doctor-like relationship), *collaborative* (farmers and formal researchers work together as partners and share responsibilities and decision-making power), and *collegial* (the research project relies on consensus and collective decision-making throughout the whole process) (Okali et al. 1994 after Biggs 1989, Vernooy et al. 2009). In this context, it is important to note that industrious farmers have always been engaged in experimentation and crop improvement to a certain extent, in pursuit of improved livelihood, and 'farmers' own research´ is common practice (Okali et al. 1994, Cleveland et al. 2000, Sumberg et al. 2003). Successful PPB projects encourage and support this potential.

In order to permanently enable smallholder farmers to cope with and adapt to a changing and increasingly variable climate in many regions of the world, constant and rapid variety development, as well as in situ conservation of agricultural biodiversity are necessary (Lane & Jarvis 2007, Meldrum et al. 2013). Vernooy (2003) describes a number of experiences worldwide, in which cooperation between research institutions and local farmer research committees or NGOs has reached considerable advances in diversifying variety availability and farmer empowerment.

> *"It quickly became apparent that farmers' selection criteria, largely based on environmental criteria, were quite different from those used by the national breeding programs. To the surprise of many, the selections made by the farmers were at least as effective as those made by the breeders. Yields increased in areas where plant breeding had not previously been successful."* (Vernooy 2003:21, on a case of barley improvement in North Africa and the Middle East)

PPB reduces the risk of discarding promising lines because of relatively poor performance under controlled conditions, and, most importantly, is able to take into account not only biophysical, but also socio-economic requirements, a dimension difficult to assess for researchers. Plant breeders' experience shows *"that when germplasm choice did not include farmers' ideas, traits and materials important to farm households were often overlooked"* (Ashby 2009). For instance, farmers' criteria might not be restricted to the primary produce, but also include requirements to the stubble as animal fodder, or may vary between varieties intended for marketing and for subsistence (Weltzien & Christinck 2009). Criteria like 'cooking quality' can be important in variety preference, but may be hard to assess for formal scientists (Joshi et al. 1997). PPB has also been shown to speed up the process from crossing to final variety release (Ashby 2009).

Ceccarelli (2009) splits the breeding process into three principal stages: the creation of genetic variability; the selection of desirable gene combinations; and the final on-field testing of these desirable gene combinations. Many participatory breeding programs restrict farmer involvement rather to the last step of variety assessment, in what is called termed participatory variety selection (PVS). Misiko (2013) points out that in many PVS projects, farmers' variety selections are based on a narrow temporal and spatial frame around the time of harvest, due to low participation in early stages in cultivation. Therefore, a methodology is needed which effectively fosters participation along the whole cultivation cycle, and under various environmental conditions.

Participatory approaches, including PVS, are by now considered to have reached mainstream status (Vernooy 2003, van Asten et al. 2008, Ceccarelli et al. 2009). In Honduras, bean varieties have been released after PVS since the early 2000s, and their rate of adoption exceeded that of conventionally bred varieties (Reyes 2011). However, practitioners highlight several challenges and pitfalls in participatory research and its current practice. Generally, van Asten et al. (2008) stress that participatory agricultural research risks yielding flawed, incomplete, or biased results, due to researchers' insufficient insight into agricultural system complexity, different reference frameworks among researchers and farmers, and methodological errors, such as suggestive questions. More specifically, Misiko (2013) demonstrates how PVS projects frequently do not reflect farming systems' realities: In most cases, farmer research groups engage in shared experimental cultivation of varieties on experimental plots, together with researchers. Often, attendance at crucial steps in the cultivation cycle is low, and farmers' subsequent variety selections are based on their 'snapshot' view at the field day after harvest, resulting in what Misiko (2013) calls 'impulse buying'. Producers then lack important observations and learning stages and cannot discriminate between varieties appropriately. Once under individual cultivation, unexpected plant behaviour during the growing period may lead to non-adoption of the variety. Moreover, the cultivation and selection of varieties is performed at a specific geographic site and by a limited number of farmers, so local 'spoiler factors' like extreme weather events or heavy pest incidence can distort the evaluation. Lastly, cultivation is usually supervised by researchers, who ensure that necessary labour is done (by hired workforce, if necessary), so outcomes may not represent existing constraints to farmers, like seasonal off-farm duties.

1.3.3 Crowdsourcing Crop Improvement and Citizen Science

Crowdsourcing Crop Improvement (CCI) intends to overcome the pitfalls and limitations of PVS, drawing from methodologies developed by the emerging field of citizen science (Silvertown 2009, Dickinson & Bonney 2012). Citizen science, or *crowdsourcing*, refers to a research methodology involving large groups of volunteers contributing to scientific tasks, including data collection, analysis and interpretation. 'Crowds' can fulfil tasks that centralised research cannot, because of their geographic spread, the accumulated time they can dedicate to a task, and the sheer number of contributors. Examples of well-established crowdsourcing projects include thousands of hobby birdwatchers contributing to regular national surveys on bird migration, or citizens classifying the water quality of their nearby water bodies (Sullivan et al. 2009, Conrad & Hilchey 2011). Using a citizen science approach in agricultural research, small seed packages of different crop varieties can be disseminated to large numbers of farmers, and tested under local conditions. This is expected to lead to a higher *in situ* agrobiodiversity (Joshi et al. 1997), dynamic adaptation of farming households, and strengthened climate change resilience of rural communities.

Van Etten (2011) proposed CCI as a scalable and low-input, low-interference approach to PVS, enabling the inclusion of very high numbers of farmers at different locations, and building on local potential for farmers' own research. The concept is visualised in Figure 1. Like in PVS, new crosses are evaluated by farmers, but a main feature of CCI is that varieties are cultivated on participants' regular plots and under usual management. This is meant to ensure proper observation of the varieties' qualities throughout critical stages, as well as the application of realistic conditions and constraints, like soil fertility, inclination, or pest pressure. Farmers' own research is common throughout the world and often follows this scheme, hence the trial design is expected to not overtax farmers' capacities (Richards 1989, van Veldhuizen et al. 1997, Sumberg et al. 2003). In fact, Sumberg et al. (2003) advocate that the most effective research outcomes for smallholder farmers may be achieved by their own investigation, thus

> "*[t]he need is not necessarily to improve the methods that farmers use to experiment, but to increase the supply of 'raw material', or partially specified technologies, which they can incorporate into their ongoing farming and experimental activities.*"

The supply of 'partially specified technologies', that is, preselected seed, is a core element of CCI. The seeds under evaluation can be new crosses or promising unreleased and released varieties from centralised breeding stations, or local varieties from other geographical areas or countries. Small seed packages, containing experimental quantities of three promising materials, can be disseminated via existing distribution channels, such as churches, retail stores, grass-root organisation, or, as in the case of this study, existing farmer research committees. The distribution of small seed packages for experimental plots was shown to generate strong interest among farmers and lead to adoption of new varieties (Joshi et al. 1997).

In CCI, trial participants need to register with a telephone number in order to obtain small seeds packages, which come with simple observation forms for farmers' evaluation of the varieties. The varieties should be cultivated within the farmers' regular production plots, next to each other and under equal management, carefully marking which sub-plot represents which (anonymised) variety (A, B, and C). After harvest, farmers report back their evaluation: Along the growing cycle, the varieties are ranked in various, independent pre- and post-harvest criteria, including e.g. yield, disease resistance, or preference for consumption. These criteria will depend on local requirements and selection objectives, and should be defined via participatory appraisals. Participants are asked to define the best and worst (and thereby fixing the intermediate) variety per criterion. This data may be fed back to researchers paper-based (as in this pilot study), but given the very simple structure of farmers' observations, phone calls, or even text message-based systems may be feasible and enable reaching far more farmers with less scientific staff in the future.

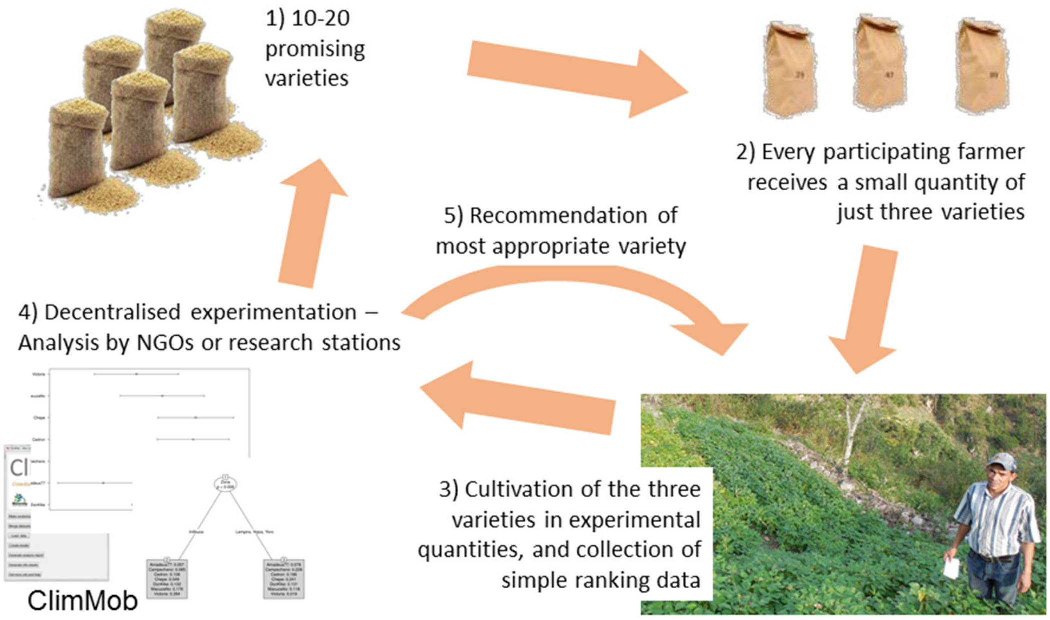


Figure 1: Conceptual visualisation of CCI (adapted from J. van Etten's presentation on slideshare, n.y.[3] Photo: Author)

Beyond the access to new varieties, farmers are incentivised to carry out the trial correctly, to not confound varieties, and to report well-considered rankings by the prospect of useful information feedback from the researchers. Hence, making the variety evaluation blind is important, since the interest in finding out the varieties' names and so being able to compare with other participants' outcomes is an incentive to farmers (van Etten 2011). Receiving information about an array of new varieties and the chance to exchange new seed with neighbours is an incentive to participate in the trial. If variety ranking data is combined with biophysical data, e.g. remote sensing data, soil data or data from weather stations, different variety performance can be attributed to environmental factors. By doing so, variety recommendations for other areas, even not included in the project, may be improved.

Using the software package and web platform ClimMob (www.climmob.net), developed by Bioversity, researchers, extensionists or NGO staff are enabled to analyse the data, profiting from a high degree of automatisation, and feedback relevant results to each participant: The names of the three varieties included in his/her trial, a recommendation

[3] http://www.slideshare.net/JacobvanEtten/ict4-agjvettencgiar (2015-08-13)

for the variety that, overall, proved most suitable for the farmer's respective environment, and information on where to access more seed.

1.3.4 ClimMob

At the core of CCI, the data analysis via the ClimMob[4] software deserves special attention. ClimMob was first released as an R-package (van Etten 2014) for stationary PC use, and has been available as an online platform, in combination with an application for Android systems since 2015 (van Etten & Calderer 2015, see www.climmob.net). The code implemented by the different usage ways is virtually equal and is the fundamental element of CCI. ClimMob relies on the Bradley-Terry model of rank analysis (BT model, Bradley & Terry 1952) and recursive partitioning of BT models (Strobl et al. 2011).

Fitting BT models is a statistical method used for defining the most likely ranking scale of various objects, based on pairwise rankings of these objects from one or many rankers. For a simple example, let twenty persons observe three trees: One oak, one chestnut and one pine tree. If all observers are asked to order the three according to their height, there will be twenty rankings, i.e. sixty pairwise comparison records for analysis. Although not all pairwise comparisons may be correct, a BT model can be fit to identify the most likely correct order, via maximum-likelihood estimation. For illustration, Tables 1 and 2 contain fictitious data for the tree height estimation (both tables represent the same data).

[4] A merger term of 'climate' and 'model-based partitioning'

Table 1: Fictitious data, 20 estimated ranking orders of three trees according to height

Observer	Highest	Medium	Lowest
1	Oak	Chestnut	Pine tree
2	Oak	Chestnut	Pine tree
3	Oak	Chestnut	Pine tree
4	Oak	Chestnut	Pine tree
5	Oak	Chestnut	Pine tree
6	Oak	Chestnut	Pine tree
7	Oak	Chestnut	Pine tree
8	Oak	Chestnut	Pine tree
9	Oak	Chestnut	Pine tree
10	Oak	Chestnut	Pine tree
11	Oak	Pine tree	Chestnut
12	Oak	Pine tree	Chestnut
13	Oak	Pine tree	Chestnut
14	Oak	Pine tree	Chestnut
15	Chestnut	Oak	Pine tree
16	Chestnut	Oak	Pine tree
17	Chestnut	Oak	Pine tree
18	Chestnut	Oak	Pine tree
19	Pine tree	Chestnut	Oak
20	Pine tree	Chestnut	Oak

Table 2: Fictitious data, 20 estimated ranking orders of tree heights, input metrics to BT model

	Actual height (m)	Times ranked first	Times ranked second	Times ranked third
Oak	25	14	4	2
Chestnut	21	4	12	4
Pine tree	19	2	4	14

Regardless of the actual tree height values in the second column of Table 2, a view at the rank frequencies in Table 2 seems to indicate that the correct order of tree heights must be Oak – Chestnut – Pine tree. Although no more than 50 percent of the observers actually stated this correct order, a BT model can be fit to data, which identifies the ranks accordingly, at the .05 percent significance level (see Table 3). As ‘Oak’ is being used as the reference value for model estimation, i.e. given a rank value of 0, the rank estimate for Chestnut is approximately -1, and for Pine tree it is approximately -2. For this example, the model was fit by applying *BTm{BradleyTerry2}* (Turner & Firth 2012) in R (R Core Team 2014).

Table 3: BT model of fictitious tree height rankings, coefficients

	Estimate[1]	Standard error	
Chestnut	-0.97	0.43	*
Pine tree	-1.94	0.49	***

[1]Reference = 0 (Oak)
* p < 0.05
*** p < 0.001

ClimMob implements BT models of farmers' rankings of crop varieties within defined criteria (see previous section). Just like in the presented example, the varieties' scores (model estimates) are calculated, thereby fixing the ranks.

In real agricultural context, the relative qualities of varieties may not be expected to be constant across different environments and cultural contexts. For instance, one variety may excel in yield in low altitudes, while a different one will attain highest yields in high altitudes. I.e., if variety rankings from low and high altitudes happen to differ significantly, an overall BT model will be fit poorly. For this reason, ClimMob applies recursive partitioning (Strobl et al. 2011): Explanatory variables (e.g. altitude) are included in the BT model, and a significant effect of these factors on variety preference/performance leads to the re-estimation of sub-models. By recursive partitioning, the cutting point (e.g. specific altitude) resulting in highest improvement in model fit is established, and two sub-models can be fit. This procedure is repeated 'recursively', testing various discrete (e.g. gender, administrative region) and continuous (e.g. age, plot size) variables as covariates, until the resulting sub-samples present no significant parameter instabilities.

Via recursive partitioning, it is possible to assign every CCI participant to the smallest homogeneous sub-sample, and thereby customise the variety recommendation. If, say, both altitude and gender lead to significant partitions, then a male lowland farmer will receive a different information output from CCI than a female highland farmer.

1.4 Objective of the study

This study aims at evaluating the CCI methodology for its appropriateness to reach its goal: Fostering seed innovation and strengthening dynamic seed systems by a citizen science approach, with the aim of contributing to climate adaptation and enhanced food security of smallholder farmers. Reaching this objective by CCI requires a number of assumptions, relating to the farmers' preferences, farmers' observation skills, gender relations, and the motivation of participants, among other issues. These assumptions are checked and recommendations for the development of the methodology are made.

CCI was first implemented in 2013 and 2014 in various regions of Honduras by the Common Bean Research Program (PIF for its Spanish acronym) of Zamorano Panamerican Agricultural College, in collaboration with two local NGOs, PRR[5] and FIPAH[6]. The number of participating farmers ranged from 40, in the first season, to 120, in the last of four pilot seasons. As shown by parallel work by Bioversity in India, CCI can be scaled up to involve thousands or even millions of smallholder farmers in the developing world (Jacob van Etten, pers. comm.). From the relatively small pilot implementation in Honduras, however, important observations can be made, to facilitate the upscaling and detect needs for methodological adaptation. The vast experience in participatory methodologies held by Zamorano and the two NGOs involved provided concrete experiences against which to assess CCI, a new methodology.

The implementation in Honduras is thus evaluated with respect to the CCI methodology's applicability and accuracy, and obstacles to upscaling, as well as stakeholders' ideas and recommendations for overcoming the latter are compiled. Where it is applicable, recommendations for the further implementation and upscaling of CCI are developed.

All in all, this study's *purpose* is a contribution to the improvement and practical development of the CCI methodology as part of Bioversity's work on smallholder adaptation to climate change, and crowdsourcing methods in crop variety research in general. As *output*, a set of tangible, goal-oriented recommendations for the methodological development of CCI will be produced.

1.5 Knowledge gaps

1.5.1 Selection of crop traits for evaluation in CCI

It is known that farmers have varying needs and interests, and thus varietal preferences can vary strongly, e.g. in function of local climate, gender, market inclusion, cultural

[5] *Programa de Reconstrucción Rural:* Rural Reconstruction Program
[6] *Fundación para la Investigación Participativa con Agricultores de Honduras:* Foundation for Participatory Research with Farmers in Honduras

preferences, access to agricultural inputs, foreseen product use, or location of plot (Defoer et al. 1997, Rice et al. 1997, Oakley & Momsen 2005, Duvick 2009, Weltzien & Christinck 2009, Asrat et al. 2010). For example, Misiko (2013) revealed a total of 21 selection criteria enumerated by rice farmers in different African locations. Clearly, when crop improvement focuses on productivity increases exclusively, the benefit of new variety releases for farmers, especially those cropping in marginal conditions, is questionable, and the low adoption rate of 'improved' varieties has been criticised for many years (Vernooy 2003, Ashby 2009).

To ensure practical relevance, any crop improvement project must take farmers' needs and preferences into account to the fullest extent possible, using participatory methods, and adapt its evaluative criteria accordingly. It has become common practice to define breeding objectives and evaluate new germplasm via stakeholder discussions (Weltzien & Christinck 2009), yet low adoption rates and field sustainability are still critical issues, even after participatory selection processes (Ashby 2009, Misiko 2013).

CCI inherently copes with the dilemma of low adoption of varieties that were selected with participatory methods: With farmers growing new varieties in trials and experiencing their advantages and disadvantages along the production cycle, they are enabled to maintain the most preferred ones – even if the analysis carried out by ClimMob eventually recommends a different option, because relevant crop traits were not covered by the evaluation. However, the purpose of CCI is not only the dissemination of varietal diversity, but also the evaluation of new cultivars with respect to their suitability in specific environments, usable in variety release procedures. Although some farmers may have other selection criteria, CCI for this end needs to ensure it includes a rough consensus, i.e. the most important ones, in order to produce useful output. In a process including focus group discussions and consultations with farmers, NGO extensionists and a senior bean breeder, seven evaluative criteria had been chosen for CCI: Plant architecture, vigour, pest resistance, disease resistance, yield, market value, and consumption quality (hereafter 'taste'). In this study, farmers' selection criteria are studied, in order to assess whether any changes to this list should be made, to increase the relevance of CCI findings.

Moreover, a CCI cycle, via ClimMob, produces trait-specific output: Information is available on which variety was ranked most pest resistant, most yielding, tastiest etc. However, this does not yet allow defining which variety overall performed *best*: One variety may be ranked highest in yield, and another may perform best for market value, and not all individual traits can be expected to have the same priority for the participants. Constructing a preference scale for the different variety traits allows defining a variety's total utility.

The preference scale of a farmer depends on a number of variables, and in turn, it is unlikely that a single variety has highest utility to all participants. As an example, Asrat et al. (2010) showed that farmers generally value environmental adaptability higher than yield potential, but there is strong heterogeneity in terms of these two attributes' relative importance, e.g. in function of gender, land ownership or labour constraints. These differences in preferences and priorities can lead to different *best* varieties. Hence, in order to inform decisions about which varieties to choose for release, not only an overall preference scale, but also the identification of significant partitions with respect to trait preference scales is of interest.

1.5.2 Accuracy of farmer observations as a method in citizen science

Methods of farmer participatory research, its value and potential have been explored since the 1980s, and have since increasingly become mainstream in agricultural research and development (Farrington & Martin 1988, Sumberg et al. 2003). It has been widely acknowledged by researchers that farmers and farmers' networks possess a rich, dynamic and site-specific body of knowledge, termed *indigenous technical knowledge* (ITK), and that integration of ITK and formal research and development may lead to more efficient outcomes (Howes & Chambers 1979, Farrington & Martin 1988, Thrupp 1989). While views of 'superiority' of formal science were prevailing at the beginning (e.g. Howes & Chambers 1979), ITK is now widely accepted as a complementary reservoir of knowledge to formal science, and synergies are often highlighted (Thrupp 1989, Johnson et al. 2003, Sumberg et al. 2003, van Asten et al. 2008). Many studies have scrutinised ITK systems and come to the conclusion of 'validating' certain views found in ITK, yet Thompson & Scoones (1994) stress that 'knowledge' may not be seen as a fixed body or stock, but rather as a social process with multiple actors sometimes battling over 'truth'. Due to its process nature, ITK may therefore neither be seen as *correct* nor *incorrect*. German (2010) argues that *"empirical foundations to local ecological knowledge may be found even behind purportedly 'erroneous' perceptions of cause and effect"*, and emphasises *"the subjective nature of questions of validity"*.

Beyond ideological and theoretical debate about the scientific correctness of ITK and its implications as a foundation for farmer participatory research – such as CCI -, it is clear that the accuracy of farmers' knowledge needs to be studied in a much more complex context. From a realistic point of view, farmers undoubtedly have extensive knowledge of their production context, but may not be expected to be agricultural experts in all aspects. Moreover, not all farmers can be expected to have the same knowledge and expertise, and some topics may be more prominent and better understood within ITK than others. For example, Bentley (1989) shows that Honduran farmers generally have intimate knowledge about both crops and wild plants, less knowledge about pests and virtually no knowledge about plant pathology. If farmers are to perform as citizen scientists, the unequal distribution of knowledge must be studied and taken into account in the project design.

Galloway et al. (2006) and Kremen et al. (2011) show that citizen scientists can make accurate observations in certain categories, but are more prone to bias or inaccuracy in others. This indicates that in any citizen science project, the degree of contributors' knowledge will have implications for the accuracy of observations. Not every question may be suitable for citizen science, and deficits in training and knowledge have been said to be potential major pitfalls for data quality in citizen science projects (Hunter et al. 2013). Thus in this study, the accuracy of farmers' observation of bean plant traits is studied with the aim of identifying potential capacity constraints and key training requirements.

In CCI, large numbers of farmers make comparative observations about crop varieties. Each trial is evaluated once only, and it is impossible to control the correctness of each observation. Nonetheless, information from CCI is to be used to characterise the varieties, potentially for release procedures, and to feedback variety recommendations to the participating farmers and other stakeholders. Thus, ensuring data quality is crucial. Any deficits in exactness of farmers' observations may be balanced by the large number of observations, still allowing statistically significant distinction of the varieties' qualities via BT models (see the example in section 1.3.4). This means the question at stake is not whether farmers observe correctly, but rather: With the given degree of accuracy, how many farmers are needed for a reliable, statistically significant distinction of different varieties? With knowing the accuracy of farmer observation, critical minimum observer numbers for significant distinction can be defined.

1.5.3 Gender equity in CCI

Grounded not only in the *Millennium Development Goals* (UN 2000), promoting gender equity has for decades already become a standard objective in development projects. It has been shown many times that promoting gender equity helps reduce poverty and enhances the sustainability of development projects (Duflo 2012, World Bank 2012). In light of the precarious situation in many developing countries, all development projects are required to take these factors into account and need to adopt adequate measures to promote gender equity, and avoid strengthening existing gender disparities. While participatory approaches to development, such as CCI, may appear inherently inclusive and empowering to both genders, projects have been criticised for focussing on local, predominantly male, decision-makers, and thus further enhancing existing gender inequity (Cornwall 2003). In extreme cases, participatory development has led to marginalisation of women and their exclusion from benefits (Mayoux 1995, Agarwal 1997).

With the aim of avoiding such effects, in this study, CCI must be scrutinised with respect to gender equity. Two points are emphasised: Participation and variety selection. Firstly, the degree of women's participation in CCI is an important indicator for gender equity, yet not an exclusive one, since women's participation and variety evaluation may be subject to male-dominated concepts or direct male interference. The quality of women's participation in CCI and moments of empowerment are equally vital components of the analysis of gender-related impacts of CCI.

Secondly, various studies demonstrate that gender can play a significant role in variety preference and trait priorities (Defoer et al. 1997, Vernooy 2003, Oakley & Momsen 2005). Agricultural households may have gendered domains of authority, e.g. between on-field labour and seed conservation (Rice et al. 1997, Oakley & Momsen 2005), which interact closely, and may have contrasting influence on variety evaluation. In consequence, if evaluation in CCI, performed by male household members, favours men's variety preferences over women household members' preferences, gender inequity is effectively enhanced. In order to understand whether the variety evaluations represent not only the participating individual farmers' view, but also the farm household, it is crucial to assess gender-specific differences in variety preferences, as well as the gender dimension of decision-making for variety choice. That is, do male farmers decide alone what variety to grow, or do their wives participate in the decision-making? With respect to CCI, are farmers' evaluations representative for the preferences of the whole farm household?

1.5.4 Motivation of farmers to participate in CCI

Participatory research relies vitally on participants' willingness to provide information. In any such research endeavour, the project's success will depend on the researchers' understanding of participants' motivation to contribute, and providing the right incentives may be crucial (Albuquerque et al. 2010), because weak motivation may result in low, selective or biased participation and inconsistent results (Rotman et al. 2012, Misiko 2013). Studying motivation will thus be crucial for the ongoing implementation of CCI.

Citizen science and crowdsourcing approaches are new methodologies, developed primarily by environmental scientists, notably population ecologists (Silvertown 2009, Dickinson et al. 2012, Wilson et al. 2013). While there is already some literature on volunteers' motivation to engage in online citizen science activities (Nov et al. 2011, Rotman et al. 2012), little has been said about the motivation of citizen scientists for *offline* participation, like environmental monitoring (Rotman et al. 2012, Singh et al. 2014). It is often assumed that motivation is largely driven by egoistic[7] affective and cognitive goals, i.e. the pursuit of personal benefit for the individual participant, like fun, learning, and social interaction (Dickinson et al. 2012, Rotman et al. 2012, Singh et al. 2014).

It must be emphasised though that citizen science has rarely ever addressed any context beyond participants' hobby sphere – projects are usually designed to create awareness among interested amateurs (Silvertown 2009), and only few crowdsourcing endeavours include participants within their professional sphere (but see Singh et al. 2014). Despite a rich body of experience with 'conventional' farmer participation in agricultural research, there has also been virtually no *crowdsourcing* work with farmers or other social groups whose livelihoods depend on natural resources. In CCI, subsistence farmers contribute to a citizen science project that addresses the core of their livelihood, agricultural production. It can be assumed that the underlying motivation will differ from the findings with amateurs, who participate as a leisure time activity.

[7] With no moral judgement implied, 'egoistic' refers to motives driven by the pursuit of personal benefit for the acting person, while collectivistic and altruistic motives refer to the pursuit of shared benefit for groups of persons including, or not including the acting person, respectively.

Participatory approaches to agricultural innovation, like participatory variety selection, have been applied for many years now, and while much research has been dedicated to farmers' motivation for technology adoption, little is known about their motivation to participate in technology development. Usually, farmers' willingness to get involved is assumed to be driven by the interest in livelihood benefits derived from participation (Johnson et al. 2003, Vernooy 2003, Weltzien & Christinck 2009). It is believed that farmers participate if the research is relevant enough to their farming experience, and other factors have received relatively little attention (but see Walters et al. 1999).

One important driver of motivation is the degree to which farmers are able to influence the research agenda, which is why in many participatory research projects, the participatory definition of research objectives with small groups of end-users is the first step (Sperling et al. 2001, Sumberg et al. 2003, Weltzien & Christinck 2008, Ashby 2009). Since CCI involves a large group of farmers remotely, it is difficult to do agenda setting in a truly participatory way. However, the research objective – improving the availability of locally adapted bean varieties for the improvement of livelihood and food security – was defined in consultation with local NGO staff and researchers with long experience in participatory research, as well as with representatives of local agricultural research committees. But beyond research agenda setting, many more factors can be expected to influence farmers' motivation to participate in CCI (Bangura 1983, Walters et al. 1999, Albuquerque et al. 2010).

As part of the effort to facilitate the upscaling of CCI, the motivation of participants needs to be studied. In order to ensure sufficient participation and data quality, information on farmers' motivation must be exploited, so CCI projects can adapt the incentive structure, and avoid any motivational barriers that may reduce participation.

1.5.5 Upscaling of local experiences

Crowdsourcing Crop Improvement is explicitly designed to be a scalable methodology. In his proposal of CCI, van Etten (2011) emphasises that the crowdsourcing approach to seed innovation

> *"builds on lessons learnt from participatory crop improvement over the last two decades, yet adds an important component to make it possible to upscale local efforts to a system that would have an impact on large populations"*

and suggests that

> *"the scope for upscaling the crowdsourcing approach should be clear from the start."*

The theoretical foundations of CCI support the feasibility of massive upscaling: Diverse citizen science projects have achieved remarkable research results (Hand 2010), the ranking of three crop varieties is a simple task that virtually any farmer can perform with little to no facilitation (Martin 2004), and mobile phone usage as well as network coverage are growing fast in the developing world, including the rural areas (Kalba 2008), which may boost upscaling via phone-based data collection from farmers (Aker & Mbiti 2010). Nonetheless, adoption, upscaling and effective success of CCI will depend on the methodology's local adaptation, which is why *"[i]Implementation should be organised in stages, iteratively refining the system, starting with tests on a small scale, and building on previous related experiences"* (van Etten 2011).

Aker and Mbiti (2010) advocate the use of mobile telephone technology for rural development. The increasing coverage and affordability of mobile phones now makes it possible for extension services and development projects to reach large numbers of rural population, with limited resources. Mobile phone technology has been used in different development sectors, such as agriculture, health and adult education, and in multiple countries (Aker & Mbiti 2010). Phone-based services are often used for the dissemination of information, yet in CCI, mobile phone technology might also be used in the collection of data (van Etten 2011). Extensionists may call farmers to collect their observations about the trials, or ask them to send the data via text messages. Such system would drastically reduce cost and labour effort of the project, thus enabling working with a much larger number of farmers. In this study, special attention is paid to the feasibility of upscaling CCI through data collection via mobile telephones.

In 2014, just 120 farmers participated in the CCI project of red common bean in Honduras. For the upscaling of CCI, methodological pitfalls must be identified empirically at this early stage. Accordingly, conclusions can be drawn on appropriate methodological adaptations. In Honduras, CCI relies predominantly, yet not exclusively, on CIAL infrastructure. Existing CIALs have been 'entry points' for the methodology, and at the third project cycle, the majority of participants were still direct CIAL members. Strategies are needed for the massive inclusion of independent farmers, beyond the limited scope of CIALs. By identifying the methodological obstacles constraining the expansion beyond CIAL infrastructure, such strategies can be developed. While implementation of CCI in other countries and with other crops will require case-specific adaptations, some conclusions about upscaling may still be generalisable.

1.6 Research questions

1 Selection of crop traits for evaluation in CCI

- Does CCI include the most important selection criteria of participating farmers?
- What is the relative importance of each variety trait for the overall variety preference of all farmers?
- Which factors explain differences in participants' preference scales for variety traits?

2 Accuracy of farmer observations as a method in citizen science

- How accurate are farmers' observations in CCI?

3 Gender equity in CCI

- How gender-inclusive is participation in CCI?
- How gender-inclusive is the variety evaluation in CCI?

4 Motivation of farmers to participate in CCI

- What motives drive CCI participants' willingness to engage in the trials?
- What incentives are most effective in motivating participation?
- How can these incentives be enhanced in CCI?

5 Upscaling of local experiences

- Which obstacles did CCI stakeholders perceive and can be observed?
- How can these obstacles be overcome by methodological adaptations, for massive and location-unspecific upscaling of CCI?

2 Material and Methods

2.1 Study region

Honduras is situated at the centre of the Central American land bridge. With a variable climate affected by two oceans and a strong relief, conditions for agriculture are highly diverse. Although only about 20 percent of the economically active population work in agriculture, 48 percent of the country´s population live in rural areas (FAOSTAT 2010), often depending on subsistence family farming of maize and beans for food security. About 80 percent of small-scale farming in Honduras is located on hillsides (Ruben & Van den Berg 2001), given the country´s strong physical relief. Smallholders seldom farm more than five hectares, and mostly rely on rainfall, low input usage, and marginal soils on hillside plots (Tshering 2002, Rosas et al. 2003). Nonetheless, over 70 percent of the Honduran production of common bean is performed by smallholders (Rosas et al. 2001), underlining their vital role for the country's food system.

Gender disparities in Honduras are strong, particularly in terms of education, asset ownership and economic activity (Deere et al. 2010, UNDP 2011). In the UNDP's ranking of Gender Inequality Index, the country ranks 105th among the 187 countries and territories listed (UNDP 2011).

Research was carried out in four different regions of Honduras (see Figure 2). All regions are dominated by small-scale subsistence farming, but environmental conditions and certain socio-economic characteristics (like the preferred seed colour in bean) vary. Most family farmers rely on maize as a staple crop, and both coffee cultivation (in high altitudes) and foreign remittances are typically important sources of financial income.

The region around the Yojoa lake (hereafter abbreviated as 'Yojoa region') is a medium altitude area (~ 600-900 m.a.s.l.) with very high levels of precipitation. In addition to growing maize and beans, banana, and, to a smaller extent, coffee are important crops. Participatory research has had much impact here over the last 25 years due to the activity of the NGO PRR.

Yoro is a district in the Northern part of Honduras. Research was carried out at medium to high altitudes (> 600 m.a.s.l.). Smallholder farmers typically cultivate maize and beans, and often generate additional income with coffee and avocado or mango trees. This region is the main bean area of Honduras, and bean yields are very high at the national average, which makes it an important commercial crop. Participatory research and extension by FIPAH have a long history in Yoro, and the first CIALs in Honduras came into being here.

Intibucá, located at the border to El Salvador, is part of the *dry corridor*, a semi-arid landscape including parts of Honduras, El Salvador and Guatemala. Research was carried out in medium altitudes (600-900 m.a.s.l) in communities belonging to the municipality of Jesús de Otoro. Due to the relatively dry climate, some farmers cultivate sorghum alongside maize.

Figure 2: Physical map of Honduras, research regions are marked in green colour. Adapted from: http://www.lib.utexas.edu/maps/americas/honduras.jpg (2015-08-13)

Lempira is the most arid district of Honduras. Poverty among rural population is more extreme than anywhere else in the country. Many communities are not yet connected to electricity. Due to low levels of precipitation and sometimes destructively strong winds at high altitudes, yields are relatively low, and smallholders typically realise one harvest per year, in contrast to two harvests in the other three research regions. Sorghum is a relatively common crop, while bean is rather uncommon, due to low yields. Research was realised in communities of the municipalities of San Andrés and Santa Cruz, at high altitudes (> 1700 m.a.s.l.).

2.2 Methodological approaches to the research questions

2.2.1 Methodology for research question 1: Farmers' trait preferences

1 Stated selection criteria

To answer the research questions in section 1.6 (1), three steps were undertaken: Firstly, 37 CCI participants from all four study regions were interviewed about their production habits, variety usage and their experiences with participating in CCI (section 2.3.1.1). All respondents were either part of a CIAL carrying out a trial at the time of the interview (late 2014), or managed their own trial at either the time of interview, the previous season, or both. The interviewees were asked to enumerate the bean varieties they most commonly used, along with the reasons why each specific one was used. These stated preference criteria were used as a proxy for farmers' selection criteria for further varieties, because they reflect their likes and priorities. Although they are derived from current varieties and thus do not cover selection criteria that no variety currently excels at, this is seen as a minor limitation: It is unlikely that breeding will ever produce 'new' trait categories, but it will rather enhance current priorities. Hence, with the cumulative importance of these preference criteria in farmers' statements, the first research question can be answered, and the inclusion of the participants' most important (i.e. most commonly mentioned) selection criteria in CCI can be assessed. The analysis was further backed by information given by the participants of various focus group discussions (cf. section 2.3.2) and the key informants (cf. section 2.3.1.4), and by qualitative statements made by participants in the pairwise choice experiment (section 2.3.3.2).

2 Conjoint analysis

With regard to the second research question, a Lancasterian utility framework was applied, grounded on Lancaster's theory of consumer demand (Lancaster 1966). This theory assumes that consumers derive utility not from a good itself, but rather from its underlying properties, and a good's overall utility is the sum of multiple part-worth utilities. Based on this theory, conjoint analysis, also called stated preference or stated choice analysis, aims to reveal the relative importance of multiple attributes of different concepts for the ranking or rating of these concepts – the *stated choice* of a respondent (Bunch et al. 1996, Louviere 2000). It is a common concept in marketing research, where participants are asked to state their preferences among, say, cars which differ in speed, size, and cost. Implicit trade-offs between attribute levels lead to the final preference choice. As a consequence, overall utility (of a car, or a variety) can be decomposed into partial utilities, and can be described as a multivariate function of the respective attribute levels (of, e.g., speed, size and cost) (Tano et al. 2003, Asrat et al. 2010). From the preference data, a utility function can be fit, where the estimated coefficients of variables included in the function represent the partial utilities, or stated otherwise, the relative importance of variables (i.e., car attributes, variety traits).

Hence, in the stated choice experiment, farmers were confronted with a number of choice sets of two hypothetic varieties with different levels of four out of the seven variety attributes included in CCI (section 2.3.3.1). By making an intuitive choice about which set of attributes they prefer over the other, participants implicitly reveal their preferences.

When a respondent is confronted with a choice set of two varieties, with four attributes each, the acceptance of the first profile over the second one can be written as a binary response Y with 1 for acceptance and 0 for reject (i.e. acceptance of the second profile). The acceptance of the first profile will depend on the attributes involved, on their levels, and on the relative importance of each attribute for the individual.

The probability of acceptance in the stated choice experiment may then be expressed as a standard multivariate logistic regression:

$$p(Y = 1) = \frac{e^{\beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 + \beta 4 X4}}{1 + e^{\beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 + \beta 4 X4}}$$

where $\beta_{1,\dots,4}$ are the part-worth utilities driving choice, X_i are the respective four attribute levels, and β_0 represents a base event rate (if $\beta_{1,\dots,4}$ all were zero, meaning none of the four attributes had any relevance for acceptance, then β_0 may be expected to account for a random acceptance rate of 50 percent).

This model can be linearised by transforming the odds of the response to logit[8], turning the logistic regression into a linear model:

$$Logit(p(Y = 1)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

[8] $Logit(Y = 1) = \ln(odds(Y_{1|0}) = \ln(\frac{p(Y=1)}{p(Y=0)})$

With the stated choice of 25 participants, a main effects model of CCI participants' preference scales and the part-worth utilities of the seven variety traits could be fit. This way, each attribute's relative importance was calculated.

3 Pairwise choice

As preferences and trait priorities may vary due to many factors, it is important to identify which farmer characteristics interact significantly with preference. In consequence, separate preference scales for each discrete group can be modelled, potentially leading to different *best* varieties, and different variety recommendations. In response to the third research question – Which factors explain differences in participants' preference scales for variety traits?, a pairwise choice experiment was designed to identify significant partitions of the trait preference scale along the following continuous and discrete variables: age, gender, number of household members, research region, and municipality (section 2.3.3.2).

A pairwise choice experiment was designed in addition to the more complex stated choice experiment, because this way, higher-level interaction between attributes can be excluded. In dilemma situations, farmers were required to make a choice between, e.g., a high-yielding, but bland variety, and a low-yielding, but tasty variety. The respondents' choice for either of the options can then be solely attributed to their preference for the high-level trait. By crossing every trait with each other one, and hence performing a maximum number of dilemma choices, a full hierarchy of traits may be constructed for every participant, and partitions in between individuals' preference scales can eventually be attributed to the test variables.

Pairwise comparison of two objects at a time, out of a larger number of objects, allows the construction of a simple preference scale, in which the number of pairwise 'wins' determines the object rank (Martin 2004). With seven objects (e.g. variety traits), one object can be expected to be preferred over six other ones, another object will 'win' over the subsequent five, and so on, assuming a coherent preference scale (e.g. excluding ties). Pairwise comparison may also be expected to be a fairly easy exercise for most people, since it requires choosing the better option from two objects at a time, only, instead of having to put a whole lot of objects in order. When the preference scale of a group of individuals is of interest, it can be modelled using Bradley-Terry models (Bradley & Terry 1952). In practice, BT models are used to attribute 'overall' ranks to a number of objects ranked by a group of observers via pairwise comparison (see Strobl et al. 2011 for examples). In this study, the objects were the seven bean variety traits (see section 1.5.1), and a preference scale of these attributes was constructed, ranking the traits from the most important to the least important, in the participating farmers' perception. As preferences can differ strongly for different groups of people, it is common practice to stratify the respondents into subgroups and fit separate BT models, to account e.g. for differences in preference structures of younger and older individuals (e.g. Kissler & Bäuml 2000). Here, recursive partitioning (Strobl et al. 2011) is applied, to identify which ones among a variety of farmer characteristics explain significant partitions in preference scales. As potential explanatory (splitting) variables, farmers' age, gender, number of household members, (research) region, and municipality were assessed.

The seven variety traits were ranked by participants (n=39) implicitly, by picking a preferred alternative in a dilemma situation. The creation of dilemmas is a response in experimental design to the fact that respondents are expected to find it difficult to simply weigh the importance of two traits without being provided a tangible value. Since marginal utilities of trait improvements may depend on the trait level (Sy et al. 1997), it can be assumed that confronting participants with the question *"Which is more important to you, pest resistance or market value?"* will be perceived as fairly abstract, and potentially be interpreted differently by respondents with different trait levels in mind. More reliable results may be achieved by confronting participants with realistic, but simple trade-offs.

A BT model of trait preference was fit, with the farmer variables as covariates. This way, an 'overall' preference scale could be defined (complementing the attributes' relative importance values assessed by conjoint analysis), and, more importantly, the variables interacting significantly with preference were identified.

2.2.2 Methodology for research question 2: Accuracy of farmer observations as a method in citizen science

It was intended to assess the accuracy of farmers in correctly distinguishing varieties within defined criteria. Accuracy has two components: (i) trueness, or validity, and (ii) precision, or reliability (ISO 1994). Validity refers to the closeness of a result or the mean of a large group of results to the actual, 'true' value or accepted standard. It can also be seen as a measure of systematic error in measurement. The reliability of a method is its ability to produce repeated, consistent results. It can therefore be seen as a measure of random error (see Figure 3).

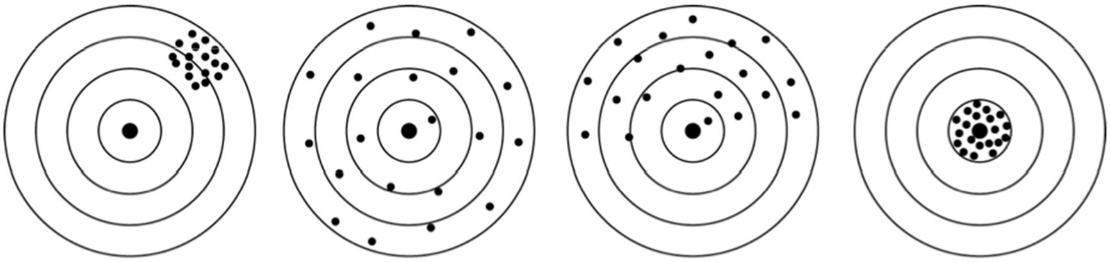


Figure 3: The two components of measurement accuracy: Reliability and validity. Adapted from Sim & Wright 2000.

In the context of the method of interest in this study - farmers' rankings of bean varieties in CCI trials -, validity means the degree of agreement of the observations with an expert-assessed standard, and reliability is expressed as the degree of agreement among the farmers about the ranking of varieties. For the assessment of both variables, group activities were organised, in which multiple farmers were asked to individually perform the evaluation of one same plot (section 2.3.4.1). Participants ranked the three varieties within four pre-harvest attributes: 'Vigour', 'plant architecture', 'pest resistance', and 'disease resistance'. An expert observation by an extensionist or field facilitator was recorded as standard. This data allowed approaching validity and reliability in the following ways:

For the analysis of validity, two methods were employed: Firstly, *Kendall's tau distance* (τ, Kendall 1938) is a measure of (dis)similarity between two ranking lists. With lists as short as three objects, it can tan take the integer values 0, 1, 2 and 3, increasing with the two lists' dissimilarity. The τ between two ranking lists is the number of pairwise rankings that need to be turned over in order to transpose one list into another. For example, if the correct ranking pattern is ABC, then ACB is more similar ($\tau = 1$) and thus 'more correct' than CBA ($\tau = 3$). For the first, there is agreement about 'A better than B' and 'A better than C', and the only inconsistent pairwise ranking is between B and C, while the latter is completely opposed to the correct order. Since each pattern is a permutation of the correct order, the distance between an observed pattern and the expert standard is a measure of that single observation´s validity. The share of each distance value among all observations and the mean distance value for all observations allow conclusions about the overall validity of farmers' observations in CCI.

Secondly, a Bradley-Terry model was fit to the observed frequencies of the variety ranking patterns (‘ABC’, ‘CAB’ etc.). If all observers agree on ‘ABC’, then a BT model will yield three significantly distinct partitions, i.e. A is significantly ranked higher than B, which is again significantly ranked higher than C. If, however, there are various different observed patterns, a significant partition between the expert-assessed best and the worst may still be possible, even with small observer groups, indicating that the observers, as a group, reliably distinguished the best from the worst. In consequence, if the BT model of farmers’ observations generates a significant partition ($\alpha = .95$) between those two varieties the experts evaluated as best and worst, then farmers’ rankings can be seen as a valid method for the distinction of varieties.

While there are different coefficients related to inter-rater reliability, an appropriate coefficient to express reliability in presence of data consisting of multiple dependent rankings is Kendall´s *W* (Kendall & Babington-Smith 1939). Kendall´s *W* may take values ranging from 0, representing completely random results and no noticeable concordance among observers (rankers), to 1, meaning total agreement among all observers. Given there is no metric for accuracy, the combined information about validity and reliability enables the discussion of the accuracy of farmer observation (ISO 1994).

2.2.3 Methodology for research question 3: Gender equity in CCI

The process and impact of development projects can be evaluated using *gender-sensitive indicators* (CIDA 1997, ADB 2013). Gender-sensitive, or gender equality indicators are quantitative or qualitative measures of performance, which describe (among other issues) “*differences in participation, benefits, outcomes, and impacts for women, men, boys and girls”* (ADB 2013).

For the evaluation of the CCI methodology with regards to gender equity, focus is laid on two topics of interest: The gender-inclusiveness of participation and the gender-inclusiveness of the variety evaluation performed by the participants. Hence, in line with the research questions described in section 1.6 (3), the indicators shown in Table 4 were defined.

Table 4: Gender-sensitive indicators

Participation indicators	1	Share of women participants
	2	Evidence of facilitation for women participants
	3	Evidence of women's empowerment through participation
Evaluation indicators	4	Evidence of gender-neutral variety preferences
	5	Evidence of intra-household negotiation/agreement on variety selection

Except for the first indicator, which is discussed based on a trial registration list, the information for all other indicators was triangulated from at least two sources (see Table 5).

Table 5: Methods used for triangulation of information on gender-sensitive indicators

Method	See section	Indicators (Table 5)
Key informant interview	2.3.1.4	2, 3
Women CIAL members focus group discussion	2.3.2.2	2, 3, 4, 5
Rural women focus group discussion	2.3.2.3	3, 4, 5
Pairwise choice experiment	2.3.3.2	4

Information on indicator 2, *Evidence of facilitation for women participants*, was collected via a focus group discussion which was held with women CCI participants. Another focus group discussion with rural women, most of which held a leadership position in their community, was conducted to add to the information, as well as a key informant interview with Marvin Gómez, a CCI extensionist with FIPAH. Any information about elements of CCI specifically directed to fostering participation of women farmers and community members is assessed as evidence of facilitation for women.

For indicator 3, *Evidence of women's empowerment through participation*, the focus group discussions, and the key informant interview were analysed. Women's empowerment refers to activities leading indirectly to enhanced participation of women in CCI, by strengthening women's positions within their community and within mixed-gender CIALs, e.g. by evening out gender-specific differences in agronomic capacity.

Findings on indicator 4, *Evidence of gender-neutral variety preferences*, are derived from the two all-woman focus group discussions and from the pairwise choice experiment revealing participants' trait preferences. This indicator is included in the analysis because gender-specific variety preferences may in fact lead to increased gender disparity: If variety evaluation in CCI is predominantly performed by male farmers, and if men have different preferences than women, then the seed innovation and adaptation measures will respond to men's preferences, but disfavour their spouses and other women community members. However, if variety preferences are likely to be gender-neutral (indicator 4), then any household member can perform the evaluation in a representative manner, and seed innovation will benefit both genders, i.e. the whole farming household.

Indicator 5, *Evidence of intra-household negotiation/agreement on variety selection* refers to any interaction between wives and husbands about variety choice. These interactions can be expected to promote gender equity, because variety selections and cultivation decisions are discussed and negotiated within the household, between male farmers and farming or non-farming women. Since even women who do not actively take part in field activities of crop production have variety preferences, e.g. as consumers (culinary qualities) or food processors (cooking time), gender disparities may increase if women have no say in the choice of seed, and men pursue their perception of seed innovation without negotiation with their wives. Information on intra-household interactions about seed choice is gathered via two focus group discussions, with women CCI participants, and non-participant rural women.

2.2.4 Methodology for research question 4: Motivation of farmers to participate in CCI

Motivation is a construct in humanities used to explain *the "initiation, direction, intensity, persistence, and quality"* of behaviour (Brophy 2004). While there are many different, sometimes compatible, approaches to studying motivation (cf. Pardee 1990, Brophy 2004), this study applies incentive theory, firstly because it is a common and well-established concept to explain behaviour in social context, and secondly, because this study seeks to identify the incentives most likely to increase participation in CCI. Incentive theory refers to a dominant school of thought in motivation science that sees human beings as fundamentally active (thus, there is no need to explain why persons behave at all), and responsive in their behaviour to *reinforcement*, i.e. incentives (Brophy 2004). While early theories of behaviour focussed on needs (e.g. Maslow 1962), picturing human behaviour as mainly reactive (e.g. the physical need of hunger leads to energy intake via eating), modern behaviourist approaches emphasise the importance of goals, which lead to proactive behaviour (e.g. the goal of enjoying nice meals leads to buying preferred ingredients for stock).

Incentive theory distinguishes between intrinsic motivation and extrinsic motivation (or: incentives). Intrinsic motivation refers to *"doing an activity for its inherent satisfactions rather than for some separable consequence*" (Ryan & Deci 2000). It is a construct commonly used to explain the propensity of persons to study, play a game, do sports etc. out of interest, or to derive enjoyment. Extrinsic motivation is defined *as "a construct that pertains whenever an activity is done in order to attain some separable outcome"* and for an *"instrumental value"* (Ryan & Deci 2000). There is an endless variety of *separable outcomes*, like the tangible product of having built a chair, to any kind of reward, e.g. given by a teacher, to the better job chances after studying hard, or even avoidance of penalty.

The framework used in this study follows incentive theory, and uses definitions by Brophy (2004), where *motives* are defined as *"hypothetical constructs used to explain why people are doing what they are doing"*, *goals* refer to *"the immediate objectives of particular sequences of behavior"*, and *strategies* are defined as "*the methods used to achieve goals and thus to satisfy goals"*. Incentives are external stimuli or conditions increasing motivation, i.e. the propensity to adopt a given strategy. As an example, while feeling cold is a motive to direct behaviour towards seeking bodily comfort (the goal), the motivation to act and start searching for a scarf (the strategy) will be influenced by the warmth a scarf is expected to provide (the incentive), which eventually make the strategy a promising way to achieve the goal (see Figure 4).

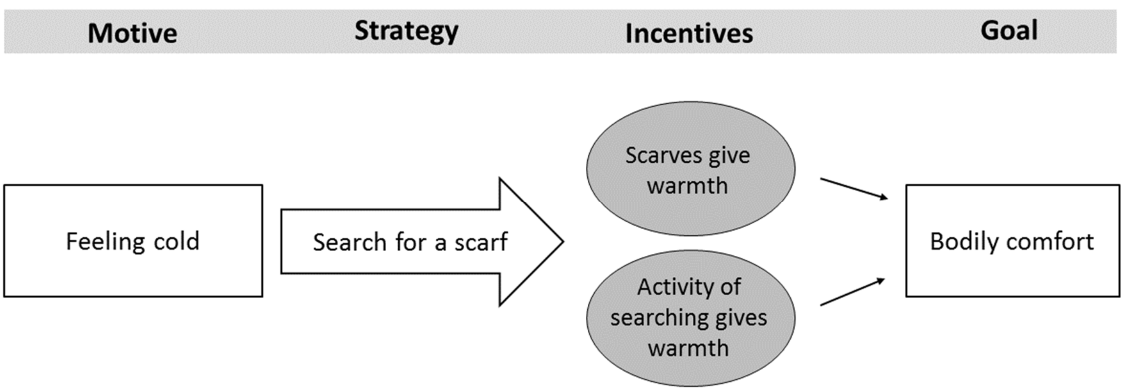


Figure 4: Motivation framework from incentive theory as used in this study. Trivial example serves clarification of terms.

Batson et al. (2002) proposed four types of motives for participation in activities with collective goals: Egoism (the ultimate goal of involvement is increasing one's own welfare), altruism (increasing other persons' welfare), collectivism (increasing the welfare of a group one belongs to), and principlism (to uphold one or more moral principles). By definition, intrinsic motives are egoistic. It has been suggested that egoistic and altruistic motives play the leading roles in citizen science projects (Dickinson et al. 2012, Rotman et al. 2012), and understanding which motives drive farmers to participate in the given context is a necessary condition to designing an adapted incentive structure for increased participation.

Thirty Farmers in 17 communities of all four research regions participated in this study by answering a semi-structured interview including questions about participants' motivation and expectations regarding CCI (section 2.3.1.2). Furthermore, observations and statements from the socio-economic base survey, including additional farmers (section 2.3.1.1), key informant interviews (section 2.3.1.4) and various focus group discussions (section 2.3.2) were used for qualitative analysis of participants' motivation. Incentive theory was applied to describe the main motivation structure for participation in CCI, including the main motives, incentives and the farmers' ultimate goal (cf. Figure 4). By qualitative content analysis, the goal, main motives, and main incentives were identified.

The qualitative analysis was further backed by a metric approach: Respondents were asked to determine their degree of agreement with seven hypothetical reasons for participation, including intrinsic and extrinsic (egoistic), as well as altruistic and collectivistic motives (section 2.3.1.2). The interviewees were asked to choose their degree of agreement with each reason: The rating scale included five verbal options, every one of which was transposed to a metric value, in order to allow basic comparative analysis of means and variance: "Very important" (2), "Somewhat important" (1), "Neutral" (0), "Not important" (-1), and "Doesn´t motivate me at all" (-2). The varying degrees of agreement with each reason assisted in identifying the main motives and incentives. This metric method, as well as the semi-structured interview about participants' motivation (section 2.3.1.2) were developed by Eskender Beza of Wageningen UR, and used within a cross-context study including farmers in Honduras, India and Ethiopia.

2.2.5 Methodology for research question 5: Upscaling of local experiences

Since it is aimed to design the CCI methodology to be scalable, it is assessed by which strategies upscaling is feasible in the given project context in Honduras. Currently observable obstacles to upscaling are identified, and suggestions by CCI stakeholders, as well as additional methodological strategies to overcoming these obstacles are discussed. During the first four seasons of implementation, in 2013 and 2014, the involved extensionists and farmers have acquired much experience with the CCI methodology. These stakeholders' perceptions of difficulty and feasibility are important inputs to an analysis of the constraints that need to be overcome for the effective inclusion of large crowds of individual farmers. In addition, direct observations from the different research regions were put together to create a classification of methodological obstacles.

This way, a variety of difficulties at different levels could be documented, namely difficulties of farmers in managing trials, observing variety traits or reporting observations (farmer-level obstacles), but also inherent methodological obstacles impeding the upscaling due to current CCI process design (project-level obstacles). As the massive upscaling of CCI will require a reduction in individual facilitation efforts as compared to the observed level, farmer-level obstacles are discussed with the objective of identifying strategies that minimise the requirement of facilitation.

Currently, CCI relies largely on CIAL infrastructure, and its coverage is restricted to selected regions in Honduras. Different project-level obstacles, leading to a restriction of the CCI project to certain participant numbers, to CIAL members, or to a specific geographic spread, are recorded and discussed with the objective of developing recommendations for overcoming the inherent constraints of a relatively restricted coverage of the CCI project.

The compiled and discussed methodological obstacles are based on the current – relatively small-scale – implementation of CCI. Suggestions for methodological adaptations to overcome the obstacles can be made, yet it is possible that an upscaled project may bring along new obstacles and challenges. Current methodological obstacles were identified via qualitative content analysis, using various sources of information:

- Three key informant interviews with extensionists of PRR and FIPAH (section 2.3.1.4)
- One focus group discussions with CCI participants (section 2.3.2.2)
- Observation of ten CCI trials in all four research regions
- Qualitative observation of farmer trial evaluation activities (section 2.3.4.2)

In addition, special focus is laid on the usage of mobile telephones for data collection, thereby decreasing efforts and costs of mobilisation. In individual farmer interviews (section 2.3.1.3), a number of variables related to mobile phone possession and usage among CCI participants was assessed. From this explorative information, recommendations about feasibility and the most likely design of a data collection system using mobile phones are derived. The interview questionnaire about mobile telephone usage was developed and made available by Eskender Beza of Wageningen UR.

2.3 Data collection and processing

2.3.1 Individual interviews

2.3.1.1 Socio-economic base survey

37 CCI participants were interviewed individually between late November and early December of 2014. Along with the stated choice experiment (2.3.3.1) and the semi-structured motivational (2.3.1.2) and telephone interviews (2.3.1.3), a structured questionnaire was employed to gather the following information: Personal data about the participants and their households, respondents' bean cultivation quantities and variety usage, agronomic variables at the site of the CCI trial, and an open-ended question as to participants' experience and recommendations about the trial. This information was searched in order better analyse the findings from other methods, linking them to socio-economic variables.

In the following, the questions of the socio-economic base survey are listed.

i) General questions:

   Age; Gender; CIAL membership (yes/no); Number of household members; Bean production in primera season (planted area and harvested quantity); Bean production in postrera season (planted area and harvested quantity); Yearly bean sales; Monthly bean consumption of the household; Yearly bean purchase; Predominantly used bean varieties and why they are used.

ii) Questions about the plot where the CCI trial was carried out:

Fertiliser used in the CCI trial (yes/no); Soil quality at the site of the CCI trial (good, average, bad); Inclination (flat, medium, inclined).

iii) Questions about CCI experience

Would you like to participate again (yes/no); What do you think about the trial and what recommendation would you like to share?

The individual interviews usually took approximately one hour. After an initial explanation of the research goal and the contents of the following interviews, these were always begun with the socio-economic base questionnaire, followed by the stated choice method and motivational/telephone interviews in changing order, flexible to the interview situation.

2.3.1.2 Participants' motivation

30 farmers who had carried out at least one trial or were in the process of doing so were interviewed about their experiences and expectations regarding the trials and CCI as a whole. All but five were CIAL members, so in general, there was a high level of previous experience with participation in research. The questionnaire was designed by Eskender Beza of Wageningen UR.

For question 3, the author explained that these options had been derived from (citizen scientists') statements in other parts of the world (e.g. Shashidharan & Shaikh n.y.). It was emphasised that there was no need to agree with any of them, and that the interviewee's personal attitude was of prime interest.

The questions were as follows:

1. Would you like to keep participating in the trials and sharing information? (yes/no)
2. Why (not)?
3. Please decide on the importance of the following, possible motives, choosing from "Very important", "Somewhat important", "Neutral", "Not important", or "This doesn't motivate me at all".

   I participate in the trials…

   - to contribute to scientific research.
   - as a pastime activity.
   - because participating is interesting for me.
   - because I am expecting something in return from the extensionists.

> What are you expecting in return? (open-ended, no options offered)

- to interact with the extensionists.
- to be in touch with the community.
- to help the extensionists do their job.

> for another reason: _____

4. Would you like to collaborate even more? (yes/no)
5. How could you collaborate more? (Any number of checks allowed)

- Giving more information about my trial
- Share seed from my trial harvest with other people
- Collaborate with other persons who are participating in the trials
- Explain the trials to others who have not participated yet
- Accompany the extensionists to other communities
- Another option: _____

2.3.1.3 Participants' telephone use habits

For the massive upscaling of CCI, aiming at reaching large numbers of farmers, the automatised or semi-automatised registration and data collection from farmers via telephones is projected as a central element. In order to explore the potential of including mobile phones in the methodology and derive recommendations for the future development of CCI, information on availability of electricity (as a proxy for reliability of phone charging), and variables of mobile phone use of thirty participants were asked. This interview questionnaire was provided by Eskender Beza of Wageningen UR. The telephone interview was merged with the motivation interview (section 2.3.1.2), hence the sample of respondents was identical.

The questions on mobile phone use were the following:

i) Base information:

Community; Respondent is household head (yes/no); Age; Gender

ii) Access to electricity:

How often are there power outages in your community?

- Never, there is always power
- Once a week
- One hour a day
- Six hours a day

- Twelve hours a day
- Other frequency: ______
- There is no power at all

iii) Mobile phone use

Phone ownership (yes/no); Monthly expenditure on airtime; Maintenance of airtime credit (always, sometimes, almost never, never);

Functions used:

- Make calls
- Send messages
- Take photos
- Internet
- None of these
- Other: _____

Frequency of using these functions:

- Make calls
- Send messages
- Take photos
- Internet

Use of phone for personal calls (yes/no); Use of phone for market/meteorological information of agronomical advice (yes/no); Sent messages before (yes/no); Received messages before (yes/no); Could always read the received messages (yes/no); If not, why not; Preference of receiving messages or receiving calls (Calls, messages, no preference); Explain your preference

2.3.1.4 Key informants

Along the course of fieldwork in different zones of Honduras, in November and December of 2014, different key informant were interviewed: Two semi-structured interviews were recorded with the main extensionists of each FIPAH (Marvin Gómez) and PRR (Pablo Mejía), two NGOs implementing CCI, and an unstructured interview about the prospects of CCI was carried out with a PPB pioneer and director of the FIPAH (José Jiménez), at which occasion notes were taken. All interviews aimed at identifying constraints observed by CCI implementers, recording their experiences and perceptions about different types of farmers, and their beliefs, visions and expectations for future upscaling of CCI, specifically in terms of extending beyond CIALs.

An interview guideline for the semi-structured interviews can be found in Annex A, and transcripts are available on request.

2.3.2 Focus group discussions

2.3.2.1 Justification of choice of method

According to Morgan (1996), a focus group discussion is defined by three characteristics: Firstly, focus group discussions are a research method intended for data collection, in that differing from, e.g., therapeutic group talks. Secondly, the interaction between discussants is the main source of data, representing the main advantage over individual interviews or fully structured group interviews. Thirdly, the researcher takes an active role in guiding the discussion to obtain information about the research objective, unlike in participant observation. Strengths of focus group discussions as a research tool, or "*what makes the discussion in focus groups more than just the sum of separate individual interviews*" (Morgan 1996) include the opportunity to observe the degree of consensus or different experiences among discussants. Because it is possible to directly ask participants to relate and compare their opinions and ask for underlying reasons of different attitudes, a more fundamental understanding of behavioural drivers can be reached (Rabiee 2004). The method may also empower respondents who would be intimidated by a one-on-one interview situation and benefit from a 'safety in numbers' effect, and has been widely shown to stimulate previously 'unresponsive' persons to engage and contribute their views to ongoing discussions, eventually (Kitzinger 1995, Rabiee 2004). In the case of the rural women focus group discussion (section 2.3.2.3), these were particularly important qualities, since the interviewer was male, came from a foreign country and some of the women had had little or no prior contact to researchers.

2.3.2.2 CCI participants

With the objective of making the CCI methodology more useful, applicable and efficient, two unstructured focus group discussions were held with groups of farmers participating in CCI in the Yojoa and Yoro areas, in November of 2014. Given that one objective of this study is the identification of any cognitive or motivational obstacles in order to derive recommendations for the pursuit and upscaling of the methodology, both bad and good experiences were of interest. Each focus group discussion was held with part of a CIAL group at a participant's home, hence the discussants represented varying levels of commitment to the trials, yet all were well informed and seemed able to form an opinion. The number of focus group participants was four and seven, of which women constituted zero and three, respectively. Women discussants in the mixed-gender group, although in minority, hardly ever seemed too shy to speak, and often took a leading position in the discussion. CIAL membership and the building of mutual trust within the group appeared to have created an empowering environment for women, as the observation does contrast with the author's observations in newly formed rural groups in Honduras, where women were more marginalised in discussions.

After some initial chatting to break the ice, the discussion was kicked off about the discussants' views on the CCI trials. No guideline was used and the discussions were left to take an almost undirected course, provided they covered experiences related to CCI. In Palmichal, Taulabé, the discussion was recorded, and in La Esperanza, Yorito, a memory protocol was constructed. The transcript and notes are available on request.

2.3.2.3 Rural women

In November and December 2014, two focus group discussions were coordinated with women discussants. One group was constituted by five women members of a newly-formed CIAL in Intibucá, and at the other occasion, in the Yojoa region, all but one held some responsibility in their local CIAL. Hence, including both leaders and new participants, the assembled groups represented a range of different views on CCI, however being perhaps not being representative of male participants' housewives. In addition to being participants with experiences to share, a female perspective on CCI and on gendered household-level differences were emphasised in these discussions. Thus, the three thematic areas covered were:

i) Gendered domains in the farm household

ii) Seed preferences

iii) Experiences with CCI

The full guideline used for the women's focus group discussions can be found in Annex B.

2.3.3 Variety trait preference scaling

2.3.3.1 Conjoint analysis

Following the 2014 design of variety evaluation in CCI, seven traits were included in the stated choice method: 'vigour', 'plant architecture', 'pest resistance', 'disease resistance', 'yield', 'market value', and 'taste'. The design of the stated choice experiment was adapted from Tano et al. (2003), who assessed the relative importance of seven cattle traits. Various authors recommend a maximum number of six traits to be included within one profile (Green & Srinivasan 1990, Caussade et al. 2005). Hence, since a design including all seven traits would require high cognitive effort in comparing variety profiles, two survey designs were created, with four traits each: Design A included the four traits expected to be most important to producers (note there is a male gender bias among producers): 'yield', 'market value', 'pest resistance', and 'disease resistance'. Design B was comprised of the remaining three traits: 'Taste', 'vigour', and 'plant architecture', as well as 'yield'. 'Yield' was included into the second design to enable linkage between the models, and because 'yield' was the trait expected to be of highest importance to producers (Misiko 2013).

For each of the seven attributes, two levels were defined (see Table 6). Although three levels, as have used Asrat et al. (2010) or Nielsen & Amer (2007), might generate more accurate results and better reflect respondents' trade-offs, the number of necessary choice sets also increases. To reduce effort for participants, a consistent two-level design was chosen. The setting of these levels per attribute is considered a crucial, yet controversial topic in stated choice analysis. Most authors stress that, e.g. "*the development of trait levels representing realistic differences is very important*" (Byrne et al. 2012). In conjoint analysis, the derivation of these values ranges from adding or subtracting half of a standard deviation, or a full standard deviation to / from the mean, to historic minimum and maximum values (Asrat et al. 2010). Another standard method is the definition of reasonable high and low attribute levels via focus group discussions (Sy et al. 1997, Alpizar et al. 2001), as was done in this study.

Out of the seven traits in this study, only two are quantitative: yield and market value. For both, there is substantial variation in time and space, both within the country (which is why nation-level data cannot be used), and within the study area, e.g. due to microclimatic variation. Thus, drawing from the local experience gained by two extensionists of PRR, reasonable levels were defined (see Table 6), representing realistic and common low and high levels in the last several years.

The use of profiles mixing quantitative and qualitative values is common (Sy et al. 1997, Asrat et al. 2010), hence for those traits that cannot be quantified easily, a binomial 'high / low' structure was used, following Tano et al. (2003). This applied to the following traits: 'Vigour', 'plant architecture', 'pest resistance', and 'disease resistance'. The appropriate vocabulary used by farmers for 'high' and 'low' values was assessed with an extensionist of PRR, and there was no need for further adaptations due to any difficulties in understanding.

Table 6: Attribute levels in stated choice experiment

Trait	**Low level**	**High level**
Yield	12 quintales[1] per manzana[2]	18 quintales per manzana
Market value	600 Lempira[3] per quintal	900 Lempira per quintal
Pest resistance	Susceptible	Tolerant[4]
Disease resistance	Susceptible	Tolerant
Taste	Bad	Good
Vigour	Bad	Good
Plant architecture	*arrastra* – crawling	*arbolito* - little tree

Stated choice experiments use factorial designs, meaning the combination of different levels of various attributes (Bunch et al. 1996, Louviere 2000). In the case of this study, a full factorial design generates $2^4 = 16$ different possible choice sets (four traits with two levels each, Figure 5). This created 16 hypothetical bean varieties to be presented to the respondents together with their contrasting profile. The full factorial design (all 16 possible variety profiles) was generated using *gen.factorial{AlgDesign}* in R (Wheeler 2014; see Figure 5). In Figure 5, '-1' stands for the low value, and '1' stands for the respective high value, while X1 to X4 represent the traits included in the design. Each line is called a fraction of the full factorial design.

[1] A *quintal* corresponds to 100 *castilian libras* (Central American pounds), approximately 46 kilograms.
[2] *Manzana* is the local standard unit of area and corresponds to approximately 0.7 hectars.
[3] At the time of this study, exchange rate was around 21 Lempira for 1 US Dollar.
[4] The term *resistant*, although a realistic attribute level for the combination of certain varieties and certain pests and diseases, was lessened to the intermediate term *tolerant*, given the fact that no variety is resistant to all diseases, or avoided by all pests.

```
levels.design <- c(2,2,2,2)
factorial.design <- gen.factorial(levels.design)
print(factorial.design)
   X1 X2 X3 X4
1  -1 -1 -1 -1
2   1 -1 -1 -1
3  -1  1 -1 -1
4   1  1 -1 -1
5  -1 -1  1 -1
6   1 -1  1 -1
7  -1  1  1 -1
8   1  1  1 -1
9  -1 -1 -1  1
10  1 -1 -1  1
11 -1  1 -1  1
12  1  1 -1  1
13 -1 -1  1  1
14  1 -1  1  1
15 -1  1  1  1
16  1  1  1  1
```

Figure 5: R code for the creation of a full factorial design (2^4) for a stated choice experiment with 4 attributes with two levels each

The generated profiles served as first alternative in a choice set. The choice set was constructed by adding a second alternative with an exactly contrasting profile. Figure 6 is an example of a choice set as presented to the respondents, constructed from fraction 10 in Figure 5.

CHOICE SET A10

Which of the following varieties do you prefer to sow? Please choose one.		
	Profile A10	*Profile –A10*
Yield	18 quintales per manzana	12 quintales per manzana
Market value	600 Lempiras per quintal	900 Lempiras per quintal
Pest resistance	Susceptible	Tolerant
Disease resistance	Tolerant	Susceptible

Figure 6: Example of a choice set constructed from a fraction of the full factorial design

By applying an orthogonal fractional design (2^{3-1}), the number of 16 choice sets was reduced to half, so interviewees would only be confronted with 8 choice sets, instead of 16 (Bunch et al. 1996, Louviere 2000, Montgomery 2013). An orthogonal fractional design treats all variables (traits) as independent, and reduces the number of experimental runs necessary to define the variables' main effects. While main effects may validly be detected, a fractional design masks higher-level interactions between variables. Hence, one major assumption in using a fractional factorial design is the low importance of interactions between attributes for the conclusions to be drawn. Since the research interest focuses on the main effects of the variety trait levels on preference (i.e. their part-worth values, Bunch et al. 1996), this condition may be accepted for the sake of experimental feasibility (cf. Tano et al. 2003, Asrat et al. 2010).

To safeguard the condition of orthogonality, i.e. the equal occurrence of all trait levels within one fractional design, the fraction of eight profiles to be used with one respondent cannot simply be drawn out of the full design. Only a limited number of fractions is valid. The fractions were defined using *optFederov{AlgDesign}* in R (Wheeler 2014; see Figure 7) and recycling the factorial design from Figure 5. The generated fractions all show an equal number of '-1' and '1' within one trait (cf. X1 through X4 in Figure 7). 50 fractions were generated, each one serving as the base for an individual questionnaire. Each fraction was used with one respondent only, but replicated with both design A and B.

The method and a few choice sets were tested with two CIAL leaders at an early stage of the fieldwork. In this activity, they used a cell phone calculator to multiply yield and market value of the two varieties they were asked to compare, in order to obtain total utility. As a consequence of this observation, the initial attribute levels were adapted in such way that any product of high*low level multiplication yields the same result (900*12 = 600*18), therefore forcing respondents to take the other traits, pest and disease resistance, into account.

All 16 possible choice sets of both design A and B were printed out, and each respondent was presented only her/his corresponding fraction of 8 choice sets. 25 CCI participants stated their preferences, each with both design A and B. Usually, the author would read out all four trait levels, for both hypothetical varieties, and then ask for the participant's choice, but some more skilled readers quickly took over and made reading out loud redundant. The method appeared easy to understand, however somewhat tedious due to its repetitive nature.

Hardly ever did farmers seem to experience difficulties in making their choices. Mostly, the decisions came quickly and intuitively, and when asked to give a reason, the preference was usually easily justified. Given that even the low attribute levels were still acceptable, many respondents tended to focus on merely one or two traits they considered most vital, e.g. consistently choosing the disease tolerant profile, regardless of the other three traits. These emphasises reflected the highly different relative importance values of the variety traits in a choice set. Routinely asking for a reason to the stated preference produced much information about the different trade-offs to producers, highly specific to the respondent's climatic and socio-economic context.

```
levels.design <- c(2,2,2,2)
factorial.design <- gen.factorial(levels.design)

fractional.design <- optFederov(data = factorial.design,
                                  + nTrials = 8,
                                  + approximate = FALSE)
randomisation.scheme <- sapply(seq_len(50), function(levels.design)
                                  +         optFederov(data        =
                                  factorial.design,
                                  + nTrials = 8,
                                  + approximate = FALSE))

# The following command was repeated, inserting the number 1 to 50,
generating 50 questionnaire designs.

print(randomisation.scheme[,1])

# Just the relevant output of print(randomisation.scheme[,1]):

$design
   X1 X2 X3 X4
1  -1 -1 -1 -1
4   1  1 -1 -1
5  -1 -1  1 -1
8   1  1  1 -1
10  1 -1 -1  1
11 -1  1 -1  1
14  1 -1  1  1
15 -1  1  1  1
```

Figure 7: R code for the creation of 50 orthogonal fractions (2^{3-1}) from the full factorial design (2^4)

2.3.3.2 Pairwise choice

For the pairwise choice experiment, all 21 possible dilemmas were constructed according to the following structure: (High level of trait 1 + low level of trait 2) versus (low level of trait 1 + high level of trait 2), an example is provided in Figure 8. Attribute levels are the same as in the stated choice experiment (2.3.3.1). With 21 dilemmas, each of the seven traits is compared with every other one (6+5+4+3+2+1 = 21). It was defined that, by choosing one alternative over the other one, respondents gave higher priority to the high-level trait in the preferred alternative, revealing more willingness to accept a low level in the lower-ranked trait than in the higher-ranked one. Hence, if the left-hand alternative in Figure 8 is chosen by the participant, market value is the higher-ranked trait, and pest resistance has higher priority if the right-hand alternative is chosen.

Variety 1	*Variety 2*
Market value 900 Lempiras per quintal	**Market value** 600 Lempiras per quintal
Pest resistance susceptible	**Pest resistance** tolerant

Figure 8: Example of a dilemma situation in the pairwise choice experiment

All respondents were asked to choose their preferred option in all dilemma situations. To speed up data collection and motivate participants in an otherwise exhausting exercise, the pairwise ranking was designed as a one-player card game which could be played by several persons simultaneously, with the author as facilitator. The game includes elements of playing cards, of *memory*, and of a kind of pictorial bingo, popular in Central America and Mexico, called *lotería*. All dilemma options were printed on cards (hence, two cards per dilemma) and designed in a playing-card-like look to enhance the feeling of playing a game (Figure 9). Table 7 shows the pictograms that were created for all attribute levels and used in the playing cards. Six full sets of 42 playing cards were created, allowing for a maximum of six participants, simultaneously.

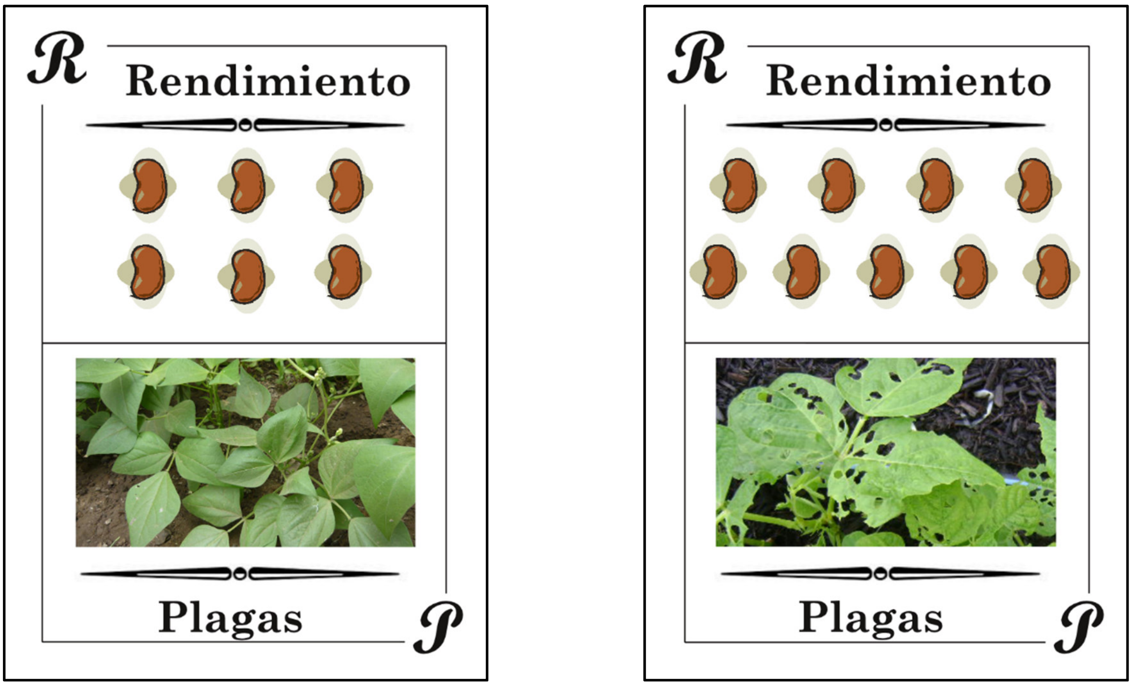


Figure 9: Example of a dilemma in the pairwise choice experiment (front sides). *Rendimiento* is Spanish for yield, *Plagas* is Spanish for pests.

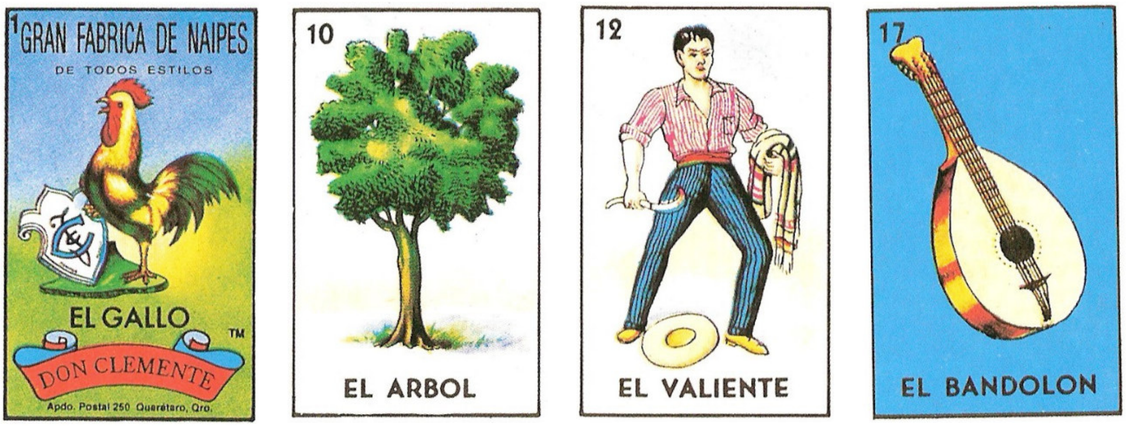
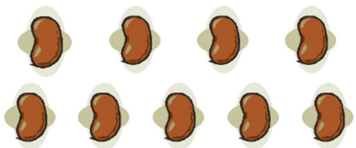
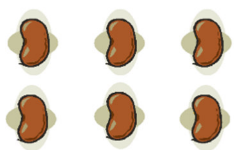
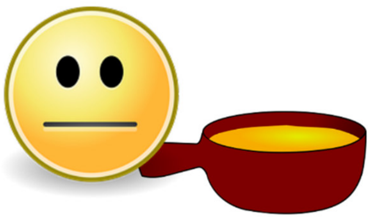


Figure 10: Selected backsides of playing cards for the pairwise choice experiment

Table 7: All pictograms used for the front sides of the playing cards in the pairwise choice experiment

Trait	High attribute level	Low attribute level
Plant architecture		
Vigour		
Disease resistance		
Pest resistance		
Yield		
Market value		
Taste		

The playing cards' backsides presented 21 images (the exact same one for both options in a dilemma), taken from a traditional Mexican *lotería*. Examples are shown in Figure 10. When all 42 cards were randomly spread out on a table in front of the participant with their backsides facing up, the game began in a *memory*-like way: Drawing from a participants' hat, containing bits of paper stating the numbers from 1 to 21, the respective image that should be searched was cried out by the facilitator (e.g. number 1 is 'the rooster', see Figure 10). Participants were then demanded to find their corresponding pair of cards (e.g. the two roosters), unveil the front sides (the playing card-like dilemmas, see Figure 9), and decide for the option they find superior to the other one, all other variety attributes held equal. Participants were asked to avoid interaction between each other on their personal decision. Most players discretely showed the facilitator their choice by raising their preferred card, whereas some engaged in vivid discussions over controversial or tough choices. Generally speaking, however, the vast majority of choices can be seen as independent. The facilitator noted down every player's choice for every dilemma.

In order to be able to identify observer characteristics with a significant effect on preference structure (explanatory variables in a BT model), the following information was then collected from each player: age, gender, number of household members, research region, and municipality.

2.3.4 Farmer trial evaluation activities

2.3.4.1 Activity design

To assess the accuracy of farmers' observations in CCI experimentally, five farmer workshops were run in November 2014, at different points in the growing cycle (see Table 8). In these activities, a group of farmers, usually members of one CIAL, regardless of prior CCI participation, was invited to visit a CCI trial. The number of participants varied between five and eight persons, and women constituted 51 % of all participants, ranging from 40 % (two out of five) to 57 % (four out of seven), so the results can be treated as representative for both genders. Since all visited trials were under individual farmers' management, the other attendees had not usually seen that specific trial before. On site, farmers were asked to take a few minutes to familiarise themselves with the three trial varieties planted, and were told the four attributes that would be evaluated later on: 'Vigour', 'plant architecture', 'pest resistance' and 'disease resistance'. The importance of independent, individual assessments was specially emphasised, and participants were requested to refrain from exchanging their ideas about the varieties, in order to guarantee independence of all statements. The attendees largely complied with this request.

After that, at the first activity, every participant was given an individual observation sheet, in which the four pre-harvest attributes were to be evaluated in just the same way as in the actual CCI: Farmers were asked to mark the ‘best’ and ‘worst’ variety for every attribute, from among the three observed varieties A, B, and C. This observation sheet can be found in the Annex C.

However, since it was realised in the course of the first workshop that the sheet is not self-explanatory and especially difficult to fill out for those attendees who were unfamiliar with CCI up to that point or had restricted literacy, the system of data collection was modified for the second to fifth workshop. In those activities, the farmers were, again, given time to observe all three varieties, but were then called individually by the researcher, to be asked the same questions verbally. Each evaluation was also performed by one expert (two NGO extensionists and two field facilitators).

Table 8: Farmer trial evaluation activities

No.	Location[1]	Total number of participants	Number of women participants	Data recording method	Plant growth stage
1	Copantillo, Santa Cruz, Lempira	8	4	Participation sheets	Early / Vegetative
2	Copantillo, Santa Cruz, Lempira	8	4	Verbal	Early / Vegetative
3	Las Cañas, Sulaco, Yoro	7	4	Verbal	Late / Pod filling
4	Las Cañas, Sulaco, Yoro	8	4	Verbal	Medium / Flowering
5	El Plantel, Victoria, Yoro	5	2	Verbal	Early / Vegetative

Two workshops were carried out in San Andrés, Lempira, where i) Farmers had little prior experience in bean cultivation, and ii) plants were at an early stage. Three more workshops were held in the Yoro region with trials at later stages in the growing cycle (see Table 8). However, due to excessive rains in the *primera* season of 2014, the planting of most trials had been delayed by the farmers, thus only two workshop trials were in the appropriate condition for pest and disease resistance evaluation. Pest and disease incidence may not be evaluated before the reproductive phase (starting approximately 35 days after sowing), so for accuracy analysis, the respective observations were taken into account for two workshops only (3 and 4 in Table 8). Nonetheless, in all workshops, farmers were asked to evaluate all four pre-harvest variables in order to increase qualitative observations about disease and pest knowledge and the general CCI experience.

2.3.4.2 Qualitative observation

Since the author carried out all workshops in cooperation with local facilitators, and collected the verbal rankings of the participating farmers, there was much opportunity for qualitative observation of the farmers' approaches to evaluating and ranking the varieties. Because the number of attendees at the workshops was relatively small, constraints and obstacles in performing the evaluation could be observed and occasionally discussed informally. All observations related to difficulties and methodologic pitfalls were written down in a field book.

2.3.4.3 Analysis of accuracy

2.3.4.3.1 Processing of field data

For each trait, participating farmers expressed the 'best' and 'worst' out of three varieties (A, B, C) planted in the trial. Any inconsistencies, like blanks (when observers were unable to decide), 'D's (when the local variety was erroneously taken into account) or 'A/B's (when observers mentioned two varieties to be equal), were removed from the data. Table 9 exemplifies the original observations as recorded, at one trial evaluation with six participants, on November 13. Statements holding any invalid observation of the aforementioned kind were excluded from the analysis and are shown shaded.

By inserting the implicit 'medium'-ranked variety, every individual observation could be converted into a ranking pattern, in the style of *A-B-C*. Based on the respective standard ranking by the expert ('XYZ', Best-Medium-Worst), all observations on one trait could be aggregated throughout the five activities (subject to exclusions due to timing of evaluations). E.g., in table 9, the expert´s 'XYZ' ranking on vigour is *B-C-A*. Hence, while the rankings by observers 1 and 4 are perfectly congruent, the ranking by observer 5 is *C-B-A*, converting to 'YXZ'. Table 10 shows the data of Table 9, converted to ranking pattern frequencies. An overview of the metric conversion of the six possible patterns to

Kendall's tau distance (τ) is provided in Table 11. For example, observer 5 correctly ranked both B and C higher than A, but failed to rank B higher than C, so the observation converts to a $\tau = 1$.

Table 9: For illustrative reasons. Original observations in farmer trial evaluation workshop 5. Shaded fields hold invalid observations, excluded from analysis.

	Plant architecture		**Vigour**		**Pest resistance**		**Disease resistance**	
	Best	**Worst**	**Best**	**Worst**	**Best**	**Worst**	**Best**	**Worst**
Observer 1	B	A	B	A	B	C	B	A
Observer 2	C	A	D/C	A	B	C	A	B
Observer 3	D	A	D	A	D	B	D	B
Observer 4	D	A	B	A	B	A	A	B
Observer 5	D	A	C	A	D	C	n.a.[1]	C
Expert	All equal	All equal	B	A	B	C	A	C

[1] n.a. = no answer

Table 10: For illustrative reasons. Data of farmer trial evaluation workshop 5 with a remaining n = 3, converted for analysis. All data on plant architecture was not processed further because of a lacking expert standard (see Table 9).

	Vigour	**Pest resistance**	**Disease resistance**
Expert standard ('XYZ')	*B-C-A*	*C-A-B*	*A-B-C*
Frequency of pattern in observations			
XYZ	2	2	0
XZY	0	1	2
YXZ	1	0	0
YZX	0	0	1
ZXY	0	0	0
XYX	0	0	0

Table 11: Metric conversion of ranking patterns to Kendall's tau distance

Pattern	**Correct pairwise rankings**	**Kendall's tau distance to the correct pattern (XYZ)**
XYZ (expert standard)	X>Y, X>Z, Y>Z	0
XZY	X>Y, X>Z	1
YXZ	X>Z, Y>Z	1
YZX	Y>Z	2
ZXY	X>Y	2
ZYX	-	3

2.3.4.3.2 Analysis of validity and reliability

Validity: Kendall's tau distance

For the assessment of validity, the frequencies of observed ranking patterns were aggregated throughout all five workshops, in integer groups of $\tau = 0$ to $\tau = 3$. The relative share of each τ among all observations on one trait was calculated. Note that there is only one possible pattern each for $\tau = 0$ and $\tau = 3$, and two possible patterns each for $\tau = 1$ and $\tau = 2$ (cf. Table 11). The underlying sample sizes range from 11 valid rankings, from two workshops, to 26 rankings, from four workshops.

By arithmetic reasoning, a hypothetical random distribution of farmer observations would be expected to yield 16.7 % (one sixth) of all rankings with $\tau = 0$, 33.3 % (two sixth) each with $\tau = 1$ and $\tau = 2$, and another 16.7 % with $\tau = 3$. In order to estimate the probability that the difference between observed frequencies and this hypothetic random baseline be merely due to a small number of observers (i.e. if farmers' observations were basically random), confidence intervals (95 %) were constructed around the random baseline. This means: If the observed frequencies are found within the 95 % confidence interval around the hypothetical random distribution, one cannot reject the null hypothesis that the farmers' observations are random, at $\alpha = .95$. Reversely, if the observed values are found outside the 95 % confidence interval, the probability that they are still due to a random distribution is below 5 %.

Based on the observed variation within the trait-specific portions of each τ value (e.g., $\tau = 2$ was observed in 0, 0, 15 and 9 percent of all observations per trait), the confidence intervals for observations of a specific τ were calculated, both for the maximum $n = 26$ and the minimum $n = 11$. Confidence intervals depend on the population mean, standard deviation and number of observations.

For example, the mean share F of observations with $\tau = 2$ among all observations across plant traits was

$$F_{\tau=2} = \frac{\left(f_{\tau_{pa}} * n_{pa} + f_{\tau_v} * n_v + f_{\tau_{pr}} * n_{pr} + f_{\tau_{dr}} * n_{dr}\right)}{n_{total}}$$

with *f = frequency, pa = plant architecture, v = vigour, pr = pest resistance, dr = disease resistance,* τ representing $\tau = 2$, and taking into account the trait-dependent different numbers of observations (n).

The confidence intervals of the share of observations per τ value, based on the experimental data, were generated in R by using arithmetic commands (*stats* package, R Core Team 2014) and added to the values of the random baseline, as visualised in Figure 14. R codes can be found in Annex D.

Validity: Bradley-Terry modelling

For the purpose of fitting a BT model of farmers' variety rankings, the observed patterns are converted to pairwise rankings, e.g. a stated 'ZXY' is split up into three binary comparisons: 'Z > X', 'Z > Y', and 'X > Y' (> standing for 'wins over'). The cumulated observations of an observer group can be tabulated as binomial counts (for illustration, see Table 12).

Table 12: For illustrative reasons. Binomial counts of observed variety rankings on vigour (n=22)

Variety 1	Variety 2	1 wins over 2	2 wins over 1
X	Y	19	3
X	Z	22	0
Y	Z	17	5

With this data format, a BT model was fit for each of the four traits using *BTm{BradleyTerry2}* in R (Turner & Firth 2012). R codes can be found in Annex D.

Reliability: Kendall's W

Kendall´s *W* of the observed rankings was generated using *kendall{irr}* in R (Gamer et al. 2012). Observations on pest and disease resistance collected at inappropriate points in time were excluded from analysis.

3 Results and Discussion

3.1 Socio-economic base data

Basic data about the participants and their households was collected by the socio-economic base survey (section 2.3.1.1) mainly as an assisting input to analysis of the research questions. For reasons of verifiability, selected results of this survey are presented in Table 13.

CCI participants tend to be rarely below the age of 35, and only 8 % of the respondents were women. Most were members of a CIAL, yet a considerable share of the participants were not affiliated. Some of these participants volunteered to perform a trial administered by FIPAH, at an open-door event for participatory agricultural research in the city of Siguatepeque, in Octobre of 2014. Others got interested in the experiments by talking to a CIAL member, and received a trial package from FIPAH without formally joining a group. With one exception (a 14-year-old member of a 'youth CIAL'), all participants considered themselves the household head, responsible for an average of 5.1 household members. There is large variation in the amount of bean harvested in the the *primera* season of 2014 (the latest harvest before the time of interview). Given that the *primera* is the minor bean growing season (Reyes 2011), 4 farmers decided to not sow any. 12 farmers completely lost their harvest due to excessive drought. All in all, an average of 361 libras (ca. 164 kg) was harvested by the farmers who had planted bean. A part of this harvest is intended as seed for the main bean season, the *postrera* (Reyes 2011, Rural women focus group 2014). Farmers estimated their household's monthly bean consumption, yielding an average of 4.1 libras (ca. 1.9 kg) per capita. This value converts to 63 g of dry bean per day, or approximately 171 g of cooked bean (Kutoš et al. 2003). Although some extreme values seem unlikely and Rosas et al. (2001) report a "high" per capita dry bean consumption of 11.1 kg/year (just approximately half the value found here), the great importance of beans as a staple food and the primary protein source for the households included in this study is evident from this finding.

Table 13: Selected base information about CCI participants (n= 37)

	Mean	***SD***	**Extreme values**
Age	46.5	*13.6 (29 %)*	14 – 69
Share of women	8.1 %		
Share of CIAL membership	81.1 %		
Number of household members	5.1	*2.1 (41 %)*	2 – 11
Bean production in *primera* season 2014 (castilian libras)	361	*518 (144 %)*	0 – 2000
Monthly dry bean consumption of the household (castilian libras)	20.8	*13.3 (64 %)*	4 – 60
Monthly dry bean consumption per capita (castilian libras)	4.1	*2.3 (57 %)*	0.8 – 12

3.2 To question 1: Farmers' trait preferences

3.2.1 Stated preference criteria

In total, 37 farmers enumerated the bean varieties they most commonly used, along with the reasons why each specific one was used. The results reveal a high diversity of varieties in use across the four research regions: 31 distinct bean varieties were mentioned. Internet research with the search items *"Variety name"+frijol* and *"Variety name"+frijol+variedad*[5] confirmed all but five variety names as distinguishable, released cultivars. The five varieties 'El Brillo', 'Majada', 'Mel', 'Pando' and 'Puerto Rico' may either refer to local releases, e.g. by the village CIAL of La Majada, wrong or incomplete names, or wrong transcriptions by the interviewer, so the actual number of varieties in use may be higher than the 26 which could be confirmed[6]. Although the sample of interviewees is by no means equal, Reyes (2011) found farmers in the Yojoa and Yoro areas grew 33 different varieties (data collection was in 2006), a comparable value.

The farmers claimed to cultivate an average of 2.9 ± 1.1 varieties. Only three farmers mentioned growing no more than one variety, and the others gave the following reasons for maintaining multiple varieties:

- Growing different varieties in different seasons (*primera* is usually drier than *postrera*)
- Choosing different varieties for different plots in the same season (e.g. according to altitude)
- Practicing variety rotation to prevent the build-up of disease pressure
- Growing different varieties for different purposes, e.g. for market sale and for home consumption

Some farmers, especially long-serving CIAL members, voluntarily act as custodian farmers and cultivate rare varieties just to prevent their loss.

When asked to explain why each variety was used, respondents generally had no difficulty describing the strengths of a cultivar. This question was intentionally asked as open-ended as possible, to compare farmers' reasons with the criteria taken into account

[5] *Frijol* is Spanish for bean, *variedad* is Spanish for variety.

[6] These were, in alphabetical order: Amadeus, Amilcar, Arbolito Negro, Balín Rosado, Campechano, Carrizalito, Cedrón, Chele Chinapopo, Chepe, Cuarenteño, DEORHO, Don Cristóbal, Don Rey, Macuzalito, Madura Parejo, Mano de Piedra, Milagrito, Milpero, Palmichal 1, Sandra, San Martín, Seda, Talete Rojo, Tío Canela, Vaina Blanca, Victoria.

in the variety evaluation of the CCI methodology. In total, 137 reasons were given for 106 varieties. The answers were aggregated into categories and the frequencies of mentioning are listed in Table 14. Some respondents also added downsides of the varieties, and these statements are included in Table 14. Only the most important reasons are discussed in the following.

Table 14: Reasons for farmers' (n=37) use of 106 enumerated bean varieties

Reason for use of variety	**Frequency of mentioning**	**Share of all given reasons (%)**
Yield	33	24.1
Colour / Market value	16	11.7
Growth habit	16	11.7
Taste	11	8.0
Disease resistance	11	8.0
Uniform ripening	8	5.8
Fits the local climate	6	4.4
Drought resistance	5	3.6
Pest resistance	4	2.9
Cooks quickly	3	2.2
Develops quickly	3	2.2
Resistance to excessive rain	3	2.2
Develops well	2	1.5
Heavy seeds	2	1.5
Pods fill up well	1	0.7
Foliage	1	0.7
Iron content in the beans	1	0.7
Always been a good option	1	0.7
No access to alternatives	1	0.7
Did not dare to try alternative	1	0.7
Long growing cycle: Harvest falls between *primera* and *postrera* harvests of regular varieties	1	0.7
Negative characteristics of variety		
Susceptible to diseases	2	1.5
Susceptible to excessive rain	2	1.5
Yellowish leaves	1	0.7
Low market value	1	0.7
Total	*137*	*100*

Yield and market value

Yield was the most frequently mentioned reason for variety use and preference, as expected (Misiko 2013). It can be assumed that statements like "very productive" or "good yield" are a merger term representing both satisfying maximum yields and yield stability. Reasons related to high market value are within the second most important category. Farmers' statements about the colour of beans were included in this category, because the reason colour is valued by the farmers is its strong implication for the attainable market value (Key informant Jiménez 2014). It was shown repeatedly (though not for the specific context of this study) that farmers are utility-maximisers, not profit-maximisers (Lin et al. 1974, Ghazali 1982). However, in the given context, where most farmers have market access, yield and market value are the most important elements of a variety's utility (Mainor Pavón, pers. comm., Reyes 2011, Key informant Mejía 2014), and many other relevant traits (consumption-related criteria left aside) are subordinate to either one of these criteria. E.g., pest resistance is not important for its own sake, but for the implications of pest attacks for both yield and market value.

Asrat (2010, for cereals) and Misiko (2013, for rice) found that marketability and producer price are rather minor selection criteria, yet trait preferences are strongly governed by the local socio-economic context, and can hardly be generalised. Surveys on trait preferences can yield quite different priorities for distinct farmer groups, depending on many different circumstances, like culture, market access, climate, or production system (Rice et al. 1997, Asrat et al. 2010, see also section 3.2.3). While yield and market value may not be important selection criteria beyond a certain threshold, they both are vital minimum conditions for satisfaction with a variety, and its final adoption.

Plant architecture

Positive characteristics related to the plants' growth habit, like "they grow erect", "they grow prettily", or "they don´t grow too much" account for 16 % of all characterisations, and are among the second most important reasons, equal to market value-related reasons. A good growth habit / plant architecture is particularly crucial in high altitudes and humid regions like the Yojoa region, where a creeping growth habit increases the risk of crop losses to diseases, due to insufficient ventilation or pods touching the moist ground (Reyes 2011). Reversely, excessive vegetative growth, especially climbing shoots, is a wasteful resource allocation from the farmer perspective (Key informant Mejía 2014).

Consumption quality

Taste, or consumption quality, throughout the research to this study, proved to be a surprisingly relevant criterion. While in the study by Misiko (2013), taste and aroma were minor selection criteria for rice farmers in 17 countries, for bean farmers in Honduras, taste and palatability-related reasons like "very tasty" or "good for eating" constituted 8.0 percent of all reasons, ranking within the third most often mentioned criteria. This can be attributed to the importance of beans as a daily staple food for the subsistence farmers, but also to the (secondary) relevance of consumption quality for market value (Rural women focus group 2014).

Disease resistance

Disease resistance was mentioned more than twice as often as pest resistance and ranks in the third most often cited category, along with taste. This is because disease attacks are seen to be harder to perceive at an early stage, more difficult and costly to control, and generally more destructive than pest attacks (Palmichal focus group 2014, Key informant Mejía 2014). Pests are rarely seen as a serious threat and generally thought to be easy to control. Although the relative importance of pest and disease pressures varies with climate and altitude within the study regions, comments like *"I can control pests with pesticides, but with diseases, the harvest can get completely lost really quickly"* were common everywhere. Reference was often made to the high price and low effectivity of fungicides, and the shortness of time between the outbreak, when a disease can be diagnosed, and massive to total crop losses. Finding varieties that are better prepared to withstand diseases was also frequently specified as participants' goal in CCI.

Uniform ripening

Uniform ripening of the pods across the plot is a fairly important criterion which was mentioned 8 times, i.e. constituting 5.8 percent of all reasons. It is listed as a distinct reason in Table 14, yet, farmers are interested in uniform ripening primarily for the implications of maturity on grain color, and thus market value (Key informant Jiménez 2014). Farmers will always harvest a plot at one day due to the requirements in time and labour, and because partially harvested plots are commonly subject to theft of the remaining crop (Key informant Jiménez 2014). However, variable maturity of harvested beans will negatively affect marketability. Because the CCI criterion 'market value' depends on more characteristics than just uniform maturity, ‘uniform ripening’ is listed separately here, yet in CCI variety evaluation, it is implicitly included.

3.2.2 Conjoint analysis

Main effects

From the stated choice of 25 CCI participants, two main effects models were estimated, model A for design A, and model B for design B (cf. section 2.3.3.1). Logistic regressions were fit to data using *glm{stats}* in R (R Core Team 2014, code in Annex D) and were used to estimate regression coefficients, corresponding to the part-worth utilities for the variety traits ‘market value’, ‘disease resistance’, ‘pest resistance’ (model A), ‘vigour’, ‘plant architecture’, ‘taste’ (model B) and ‘yield’ (included in both models). The significance of the individual coefficients was assessed by *p*-values, i.e. the probability that the calculated (model) coefficient is larger than it ‘truly’ is. The overall models were validated using the likelihood ratio test, which compares the fit of the computed model to a null model. Since the likelihood ratio is Chi-square distributed, significance of the model could be assessed by comparing with critical Chi-square values[7]. Results are shown in Table 15.

Since ‘vigour’ proved to be of no significant effect for the response at $\alpha = .95$, model B was adjusted by re-estimating it under omission of ‘vigour’. The adjusted model is also included in Table 15.

[7] For example using this table, URL: http://www.itl.nist.gov/div898/handbook/eda/section3/eda3674.htm

Table 15: Main effect estimates of variety traits for acceptance of first variety in stated choice experiment. Values are regression coefficients estimates (standard error in brackets). The *adjusted model B* is model B excluding ‘vigour’.

Variable	Model A	Model B	Model B (adjusted)
Constant	-5.2257 (0.9403) **	-4.0422 (0.7290) **	-4.0422 (0.7044) **
Yield	0.0841 (0.0368) *	0.1527 (0.0393) **	0.1523 (0.7044) **
Market value	0.0034 (0.0008) **		
Pest resistance	0.9986 (0.2303) **		
Disease resistance	1.8231 (0.2406) **		
Taste		1.9683 (0.2611) **	1.9363 (0.2567) **
Vigour		0.2816 (0.2248)	
Plant architecture		1.4077 (0.2545) **	1.3866 (0.2511) **
Likelihood ratio (LR)	72.671[a]	76,775[a]	75,871[a]

* $p < .05$
** $p < .001$
[a] $p(\text{LR} > \chi^2) < .001$

Relative importance

The values from Table 15 were converted to assess the relative importance of all traits, as shown in Table 16. Conversion to relative importance (Ψ) followed the following formula:

$$\Psi_i = \frac{partworth\ utility\ estimate\ of\ trait\ i}{sum\ of\ all\ trait\ estimates}$$

Table 16: Relative importance of the variety traits, in percent

Variety trait	Model A	Model B	Overall
Yield	2.9	4.3	3.6
Market value	0.1		0.1
Pest resistance	34.3		17.2
Disease resistance	62.7		31.3
Taste		55.8	27.9
Vigour		*Insignificant at α = .95*	
Plant architecture		39.9	19.9
Total	100	100	100

Table 16 presents the order and relative magnitude of the traits' importance values, from the stated choice of 25 CCI participants. In contrast to the stated preference criteria (section 3.2.1), it can be seen that 'yield' and 'market value' have negligible, yet statistically significant ($\alpha = .95$) effects on farmers' preferences, and the level of 'vigour' appears to be irrelevant to the stated choice. The four most important traits, with substantial effect on variety preference, are, in decreasing order: 'Disease resistance', 'taste', 'plant architecture', and 'pest resistance'. These four traits alone cumulatively explain 96.3 percent of the respondents' variety preferences.

3.2.3 Pairwise choice

3.2.3.1 Farmer variables

Preference data on bean variety traits was collected via the *lotería* game (section 2.3.3.2) in all four research regions, with a total of 39 participants and group sizes between one and six persons 'playing' at a time. To identify explanatory variables for partitions in preference scales, five farmer variables were also assessed (see Table 17). Variability with respect to the continuous variables is given, and the discrete variables create potential subgroups of a minimum 5 members.

Table 17: Descriptive variables of participants in pairwise choice experiment

Total participants	39	
Age[1]	43.4 ± 14.0	
Gender	46 percent female / 54 percent male	
Number of household members	5.2 ± 2.3	
Participants per research region	Yojoa:	15
	Yoro:	12
	Intibucá:	7
	Lempira:	5
Municipalities	7	

[1] On average, women were younger than men (38.8 ± 15.9 compared to 47.7 ± 10.2), however, this difference is not statistically significant (p > .05, Welch´s t-test).

3.2.3.2 Bradley-Terry tree modeling

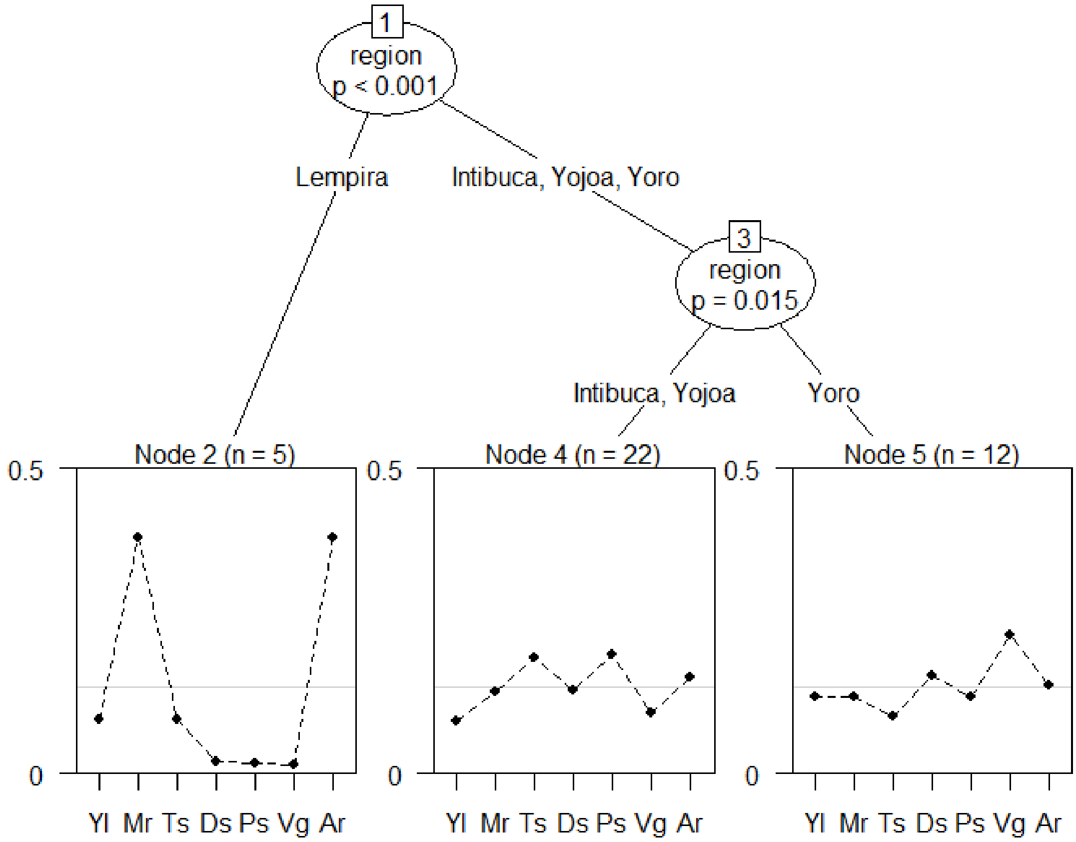
Using *bttree{psychotree}* in R (Strobl et al. 2011), a BT model for the participants' pairwise choices was fit, including the records of age, gender, household size, research region, and municipality, as potential covariates (code in Annex D). The resulting trait worth estimates are presented in Table 19, and the recursive partitioning of the BT model is visualised in Figure 11.

When the covariates are included in the BT model individually, only 'municipality' and 'research region' identify partitions, meaning both variables have an effect on players' preference scale at the .95 significance level. When both (or all) variables are included simultaneously, the region effect is stronger than the municipality effect (see Table 18). Moreover, the resulting partitions (nodes 2, 4, and 5 in Figure 11) created by including each of the two variables individually are almost identical (since all municipalities are part of a region), and 'municipality' yields no additional splits beyond what 'region' explains already. It is thus reasonable to say that region is the only significant explanatory variable for variety trait preference scaling. Neither age, nor gender, nor the number of household members exert a detectable effect on farmers' choices, at α=.95.

Figure 11 visualises three different variety trait preference scales, in function of the research region. In order to generate an 'average' preference scale that takes into account the choices of all 39 participants, another BT model was fit using *bttree{psychotree}* without including any explanatory variable. This 'average' preference scale is shown in Figure 12 and corresponds to node 1 in Figure 11. By using each of the seven traits as reference in the BT model, significant differences between trait estimates were identified and indicated by lower case letters in Figure 12. The grey horizontal line in Figure 12 is inserted for orientation: If all seven traits had equal priority (no distinguishable preferences), then all worth estimates should be 0.14 (since 1 / 7 ≈ 0.14).

Table 18: *p* values of partitions in BT models of pairwise choice, using either 'region' or 'municipality' as covariates

Variable	**Node 1**	**Node 3**
Region	$p < 0.001$	$p = 0.015$
Municipality	$p = 0.002$	$p = 0.042$



Yl = Yield, Mr = Market value, Ts = Taste, Ds = Disease resistance, Ps = Pest resistance, Vg = Vigour, Ar = Plant architecture

Figure 11: Recursive partitioning of pairwise choices in lotería game (total n=39 players).

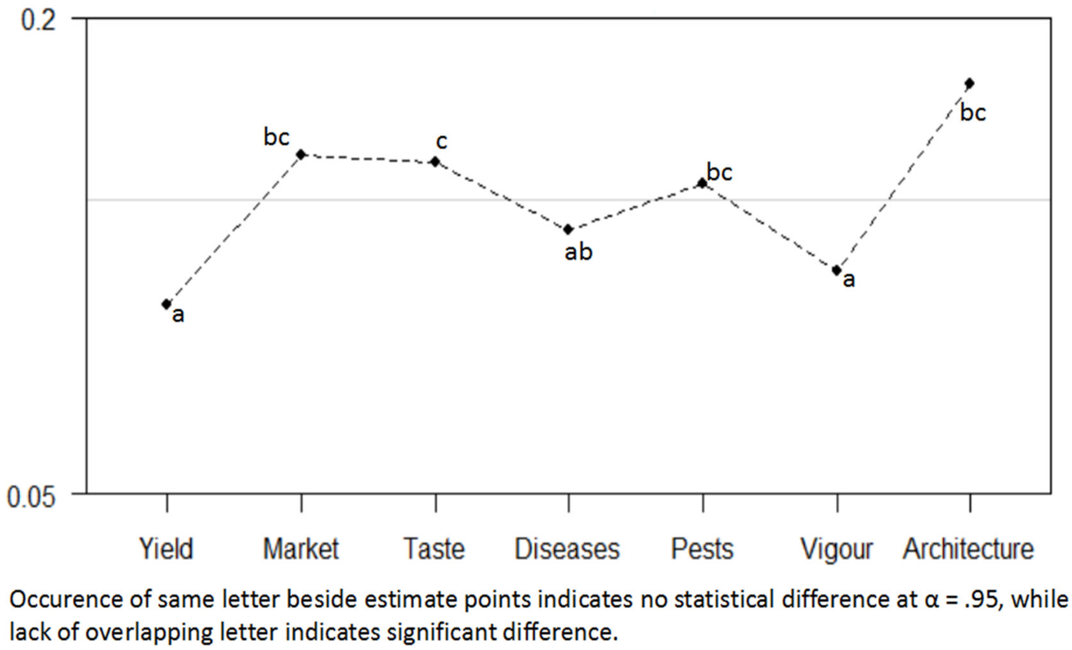


Figure 12: Node 1 of the BT model: Variety trait preference scale of all *lotería* players, without partitions (n=39)

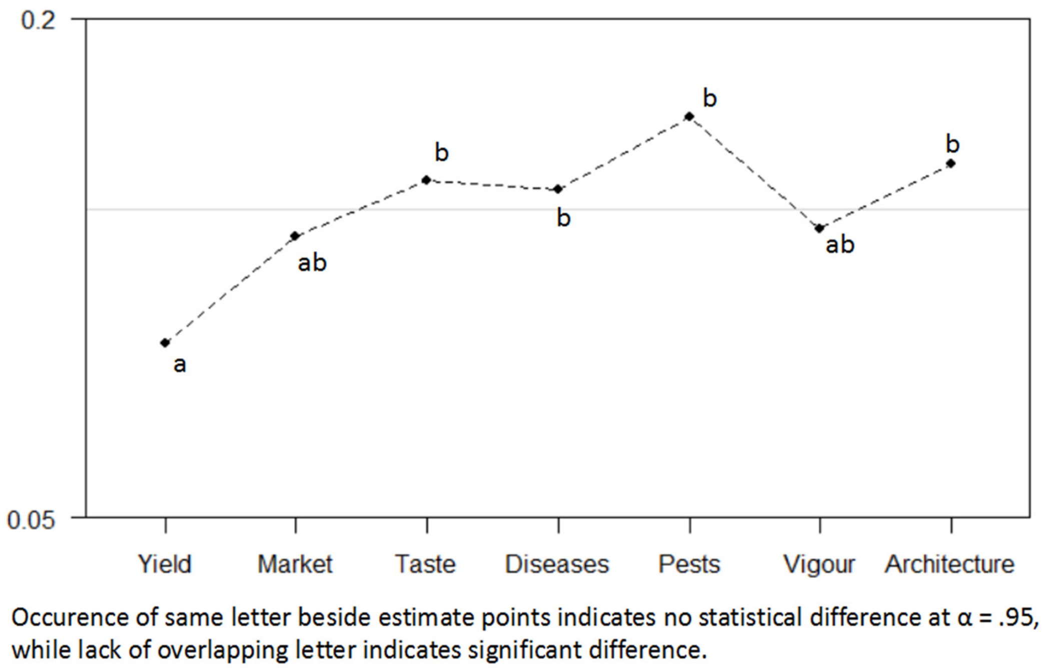


Figure 13: Node 3 of the BT model: Overall variety trait preference scale excluding the Lempira players (n=34)

The 'average' preference scale does not properly represent farmers' preferences from any research region, and its 'average' character is flawed by the different numbers of inputs from different regions. It is therefore not discussed and only visualised for reasons of completeness.

From nodes 4 and 5 in Figure 11, it is apparent that differences in between the variety traits' worth estimates are less pronounced than they are in node 1 (Figure 12) when the five players from Lempira (node 2) are excluded. By repeating the previous analysis, i.e. creating a BT model without including an explanatory variable, but now excluding the data from Lempira, node 3 (in Figure 11) can be simulated. It is visualised in Figure 13. In contrast to the 'average' preference scale represented by node 1, differences between estimates are weaker, leaving only 'yield' on one (low) side, and virtually all other traits on the other (high) side as significantly different, with 'market' and 'vigour' taking an intermediate position. Note however that node 3, too, represents a hypothetic sample and is not to be taken for an 'average' preference scale of the three research regions Intibucá, Yojoa and Yoro.

Table 19: Parameter estimates in Bradley-Terry model of variety trait preference scales

	Worth estimate, scaled to unity	Standard error	z value	p (>|z|)	Significance bands ($p < .05$)	Figure
Node 1						12
Yield	0.1097				a	
Market	0.1565	0.1729	2.054	0.0399	bc	
Taste	0.1542	0.1728	1.970	0.0489	c	
Diseases	0.1331	0.1725	1.118	0.2635	ab	
Pests	0.1475	0.1727	1.715	0.0864	bc	
Vigour	0.1200	0.1727	0.518	0.6047	a	
Architecture	0.1789	0.1737	2.814	0.0049	bc	
Node 2						11
Yield	0.0890				b	
Market	0.3858	0.6659	2.203	0.0276	c	
Taste	0.0890	0.5766	0.000	1.0000	b	
Diseases	0.0199	0.6286	-2.380	0.0173	a	
Pests	0.0167	0.6422	-2.610	0.0091	a	
Vigour	0.0138	0.6584	2.831	0.0046	a	
Architecture	0.3858	0.6659	2.203	0.0276	c	
Node 3						13
Yield	0.1022				a	
Market	0.1344	0.1853	1.474	0.1405	ab	
Taste	0.1512	0.1856	2.109	0.0349	b	
Diseases	0.1487	0.1856	2.019	0.0435	b	
Pests	0.1703	0.1853	2.740	0.0062	b	
Vigour	0.1367	0.1854	1.565	0.1175	ab	
Architecture	0.1565	0.1858	2.290	0.0220	b	
Node 4						11
Yield	0.0871				a	
Market	0.1340	0.2339	1.844	0.0652	abc	
Taste	0.1896	0.2369	3.284	0.0010	c	
Diseases	0.1376	0.2340	1.956	0.0504	abc	
Pests	0.1948	0.2373	3.393	0.0007	c	
Vigour	0.0999	0.2345	0.585	0.5583	ab	
Architecture	0.1571	0.2348	2.514	0.0120	bc	
Node 5						11
Yield	0.1253				ab	
Market	0.1253	0.3114	0.000	1.0000	ab	
Taste	0.0933	0.3146	-0.937	0.3487	a	
Diseases	0.1597	0.3119	0.776	0.4375	ab	
Pests	0.1253	0.3114	0.000	1.0000	ab	
Vigour	0.2261	0.3178	1.856	0.0634	b	
Architecture	0.1450	0.3114	0.466	0.6410	ab	

Trait preferences in Lempira

In Lempira, where the *lotería* game was played at one occasion with five participants, differences in between the attributes' worth estimates are particularly pronounced (see Table 19, Figure 11). 'Market value' and 'plant architecture' have highest preference, 'yield' and 'taste' take intermediate positions, and 'disease resistance', 'pest resistance' and 'vigour' were given low priority. The strong differences in between worth estimates can be explained by the small group size, which means unanimous views within the peer group were not levelled off by differing views in other groups. The relative unanimity among the players may be due to the fact that the CIAL members in Lempira collaborate on many agricultural activities, namely learning events and decision-making about their bean trials.

Within the greater group of participants in the pairwise choice experiment, the participants from Lempira were characterised by a number of specificities, which may explain their visibly different variety trait preference scaling: Firstly, beans had had been a crop that produced low yields, low quality produce, and was rarely cultivated, so most of the participating farmers had little to no experience with beans until improved varieties were introduced by PRR in 2013. Furthermore, the impact area in Lempira is among the driest and poorest areas in Honduras, with a particularly low level of infrastructural development and little opportunities for off-farm income. Due to low precipitation and strong winds, there is only one productive season per year, as opposed to two harvests in the other regions. Due to the lack of experience with cultivation of beans, participants can be expected to have experienced few crop losses due to pest or disease attacks. This may explain the low priority given to resistances. In contrast, the high priority attributed to plant architecture may be due to the need for varieties with wind-resistant stalks. This is an attribute local farmers seek in maize (Marvin Gómez, pers. comm.). Lastly, given the low income level of farming households, seeking marketability and profit maximisation are rational strategies, which may explain the strong importance of the product's market value.

Trait preferences in Intibucá and Yojoa

Node 4 in Figure 11 and Table 19 represent the trait preferences of participants from the regions of Intibucá and Yojoa, with no further significant partition. 'Yield' was attributed low priority, and strongest preference was given to 'taste' and 'pest resistance', while the other variety traits take intermediate positions. The estimated standard errors for the model parameters are relatively prominent, indicating there is a strong degree of variability remaining in the preference scales of this sample of 22 farmers from two regions. As a result, significance bands are broad (see Table 19). The low priority of 'yield', and the high priorities of 'taste' and 'pest resistance' are statistically robust, but it cannot be shown e.g. that the worth estimate for 'market value' is lower or higher than any other at the .95 significance level.

The findings allow the interpretation that there are other factors which may explain different preference scales, and which were not taken into account. While 'research region' is a significant explanatory variable for partitions in the preference scale, and the other assessed variables (except 'municipality') are not, other variables may lead to further partitions, more precisely defined preference scales, and less variability within terminal nodes of the BT model. Such farmer variables could include e.g. climatic variables like the average precipitation at the plot site, the degree of farmers' market inclusion, the habitual use of agricultural inputs, and others.

The small sample size of just 39 respondents might also contribute to the difficulty in identifying explanatory variables. With an increasing number of observations, small distinguishable sub-groups, and the respective explanatory variable, may be easier to detect.

Trait preferences in Yoro

The pairwise choice experiments with a total of 12 participants in Yoro yielded relatively weak differences in between trait worth estimates: At the .95 significance level, the only difference in priorities is that 'taste' is more relevant than 'vigour'. Here, too, estimated standard errors are strong, pointing at variability within the participants' preference scales. Adding further farmer variables as covariates to the analysis could have led to more partitions and could have specified different preference scales for different groups within the Yoro region.

3.2.4 Conclusions

From looking at the previous sections, the following conclusions can be derived:

- CCI covers the five most important criteria to farmers: Data supports that CCI include ‘yield’, ‘market value’, ‘plant architecture’, ‘taste’, and ‘disease resistance’ as evaluative criteria.

The five criteria most frequently mentioned by farmers as preference criteria are all covered by CCI: ‘Yield’, ‘market value’, ‘growth habit / plant architecture’, ‘taste’, and ‘disease resistance’. These five plant traits already cumulatively make up about 66 % of all reasons mentioned for plant preference (87 of 133). Accepting that ‘uniform ripening’ actually contributes to market value and is thus not truly an additional selection criterion, and excluding ‘fits the local climate’ as an umbrella term that covers various traits, the next most important criteria are ‘drought resistance’ and ‘pest resistance’. In contrast to the latter, the first has not been included in CCI.

- ‘Yield’ and ‘market value’ are vital traits that need to be evaluated in CCI, and need to be ensured at field level. However, they are not important breeding objectives beyond presently attainable levels. Yield stability is much more relevant.

At first, the information appears contradictory: ‘Yield’ and ‘market value’ have been shown to be the most important traits to participants by the stated selection criteria, and this observation is asserted both by key informants and literature (e.g. Misiko 2013). However, the relative importance of these two traits in the stated choice experiment was shown to be lowest. This is due to the mixed nature of the attribute types in variety profiles of the stated choice experiment: While the other traits, like ‘plant architecture’, were presented with two discrete attribute levels in the line of ‘very good’ and ‘very bad’, for the continuous variables ‘yield’ and ‘market value’, two realistic levels were chosen. These were neither outstandingly bad nor extremely good. By giving low priority to these traits in the stated choice experiment, participants basically expressed: The low level is acceptable in order to avoid a truly disastrous level of another trait. The same goes for the pairwise choice experiment, for instance, in which almost every respondent was willing to accept a relatively low yield potential in lieu of taking the risk of a complete crop loss due to a crawling plant architecture (which is known to lead to disease attack). Hence, while farmers are clearly interested in securing and even improving yield potential and their product’s market value, risk avoidance, mainly by improvements in disease resistance and plant architecture, are more important breeding goals. Asrat et al. (2010) show that Ethiopian farmers’ marginal willingness to pay for improvements in yield stability and environmental adaptability is, by far, bigger than for productivity increases. The same can be expected in the case of this study.

The incoherent structure of the stated choice and pairwise choice experiments, mixing discrete ('extreme') and continuous ('moderate') variables can be seen as a methodological flaw. Yet, it is possible to derive valuable insights into the trade-offs respondents needed to consider. By replacing the pictograms in the pairwise choice experiment and the text in the stated choice experiment with photographs of comparably 'moderate' good and bad attribute levels (e.g. of plant architecture or vigour), the results may better reflect the farmers' preferences facing *realistic* dilemmas (given that actual differences between varieties can be expected to be shades of grey rather than black and white).

- Diseases affecting pods are a major concern, and farmers are aware of the close link between plant architecture and disease susceptibility. In consequence, disease avoidance by tolerant genotypes, and upright plant growth are prime breeding objectives.

As was shown before, increasing yield potential has less priority to the farmers than yield stability. Interviewees consistently asserted the destructive effect of diseases, and consequently, 'disease resistance' was given high priority with all three methods employed in this section. The results from the stated preference criteria and the pairwise choice experiment seem to indicate that 'plant architecture' was even more sought after. This can be explained by the daily observations farmers make in their plots: While many are aware of different levels of disease tolerance among varieties, and some even adapt their planting decisions correspondingly, nearly all must have made the intra-varietal observation in their plots: When pods touch the moist ground due to a crawling growth habit or weak plant architecture, they are most likely to be attacked by diseases. This was explained by many respondents both in the stated choice, and the pairwise choice experiment.

- 'Taste' is an important selection criterion for farmers and may be an underestimated criterion for adoption.

In this study, taste ranged within the third-most important group (stated preference criteria), resulted second-most important in the stated choice experiment, and is among the most important group of selection criteria in the pairwise choice experiment (node 3).

Rural women asserted that bean varieties differed strongly in taste, which is an important preference criterion to them. Many breeding programs take taste, as well as product texture, cooking quickness, or a mix of these into account. However, as tastes are different and often highly location-specific, even when participatory assessments (like PVS) took varieties' culinary qualities into account, this process may have resulted in limited adoption at other locations. As unsatisfactory taste may be an important obstacle to adoption, but can hardly be assessed on-station, the highly decentralised structure of CCI can tackle this problem.

- 'Pest resistance' is a low priority trait, given the ease of chemical pest control. Drought resistance could be a more important trait, but there are practical obstacles to evaluation.

Many farmers asserted that pests were no major problem, since controlling them was easy and low-cost. Correspondingly, 'pest resistance' ranked low in the stated preference criteria (Table 14). Nonetheless, the stated choice and pairwise choice experiments do not support such a low preference for 'pest resistance'. Since chemical pest control still requires certain monetary resources, as well as the capacities to apply plant protection products, and to avoid accidentally selecting pest-susceptible varieties, 'pest resistance' should be maintained as an evaluative criterion in CCI. Environmental concerns also speak for the identification and promotion of pest-resistant varieties rather than promoting chemical plant protection.

Drought resistance, however, was mentioned more often than 'pest resistance'. In fact, the growing season preceding field research to this study was exceptionally dry and led to the complete loss of many trials and productive plots. Especially in light of changing climate, trending towards less and more erratic rainfall in all parts of Honduras (IPCC 2013), the ability of a variety to withstand dry spells may now already be a crucial selection criterion and breeding objective. In CCI, including drought resistance as an evaluative criterion may lead to false results whenever a trial has experienced no physiological drought, but drought resistance was still evaluated. Farmers may be able to deduce from other observable characteristics commonly correlated with drought resistance, like quick development or certain leaf qualities. However, in the future, coupling CCI trials with environmental sensors and precipitation maps may allow to generate a more precise picture of which variety was able to produce highest yield and highest value under conditions of low precipitation.

- Although ‘vigour’ can serve as an indicator of a plant’s resistance capacity towards abiotic and biotic stress, it is not an important selection criterion in itself, and thus might be removed from the evaluation in CCI.

There can be no doubt of that ‘vigour’, i.e. the development of a healthy foliage and a quick, competitive growth, is an important condition for a plant’s resistance to pest and disease attacks, weed suppression, resistance to drought, excessive rain, etc., and is lastly necessary for yield stability. However, it seems to play a negligible role as a selection criterion in itself, according to farmers’ stated preference criteria (Table 14). Among the evaluative criteria in CCI, only ‘vigour’ levels were shown to have no significant effect on respondents’ choices in the stated choice experiment. The results from the pairwise choice experiment support this observation, as ‘vigour’, although ranked highest in Yoro, was given low priority by farmers in Lempira, Intibucá, and Yojoa. It may be suggested to remove ‘vigour’ as an evaluative criterion in CCI, given its subordinate role for securing harvest, and its resulting low priority for farmers. However, as Jacob van Etten (pers. comm.) noted, it is often the first plant trait to be assessed in CCI trials, and its particularly easy observability make the evaluation of ‘vigour’ a useful feature to begin the process of evaluation with, to ensure farmers’ ongoing participation.

- Differences in preference scales are mainly explained by geographical region. This may be due to regionally different environments, socio-economic context and cultivation history. Preference scales within each region seem homogeneous but may be further specified along socio-economic variables.

In the BT model of variety trait preferences, using different geographic and socio-economic farmer variables as covariates, only the region a farmer belonged to was shown to be a significant explanatory variable for differences in preference scales. In part, this may be attributed to differences in environmental circumstances. E.g., different relative priorities of pest and disease resistance may be grounded on regionally different altitude and humidity regime. Moreover, in lack of a more elaborate household-level assessment of socio-economic variables for the pairwise choice experiment, region may actually be seen as a proxy, indicating the significance of various region-specific factors such as market access, average per capita income, degree of contact to extension, and more. E.g., although in Intibucá and Lempira, climate during the growing season is somewhat comparable, the strongly different preference scales may rather be explained by different income standards and experiences with bean cultivation.

3.3 To question 2: Accuracy of farmer observations as a method in citizen science

3.3.1 Validity

3.3.1.1 Kendall's tau distance

Table 20 presents the share of each τ value among all observations, and the results are visualised in Figure 14. For 'vigour', all observations have either $\tau = 1$ (36 %) or $\tau = 0$ (64 %), the latter meaning perfect agreement with the expert standard. The mean τ of all rankings is 0.4.

For 'plant architecture', 54 % of the observations have $\tau = 0$, another 23 % of all rankings are within $\tau = 1$, and another 23 percent have $\tau = 3$, indicating no agreement with the expert standard. The mean τ of all observations is 0.9, and a total 77 % of all rankings have a τ of just 0 or 1.

For 'pest resistance', 46 % of all observations have $\tau = 0$, 38 % reach $\tau = 1$, and 15 % of the observations have $\tau = 2$. No observations have $\tau = 3$. The mean τ of all rankings is 0.7, and 84 % of all observations are within $\tau = 0$ or $\tau = 1$.

For 'disease resistance', the stratum with the highest number of observations is $\tau = 1$, with 55 % of all rankings. 27 % of the observations have $\tau = 0$, 9 % have $\tau = 2$, and another 9 % have $\tau = 3$. The mean tau distance for observations on disease resistance is 1.0, and 82 % of all observations have a τ of either 0 or 1.

Table 20: Kendall's tau distance and Kendall´s *W* in experimental farmer variety rankings

Kendall's tau distance	**0**	**1**	**2**	**3**			
Patterns	XYZ	XZY, YXZ	YZX, ZXY	ZYX			
	Share of all observations (%)				**Mean τ**	**n**	**Kendall's *W***
Vigour	64	36	0	0	0.4	22	0.676 ***
Plant architecture	54	23	0	23	0.9	26	0.183 **
Pest resistance[1]	46	38	15	0	0.7	13	0.337 *
Disease resistance	27	55	9	9	1.0	11	0.174

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
[1] Values do not amount to 100 because of rounding.

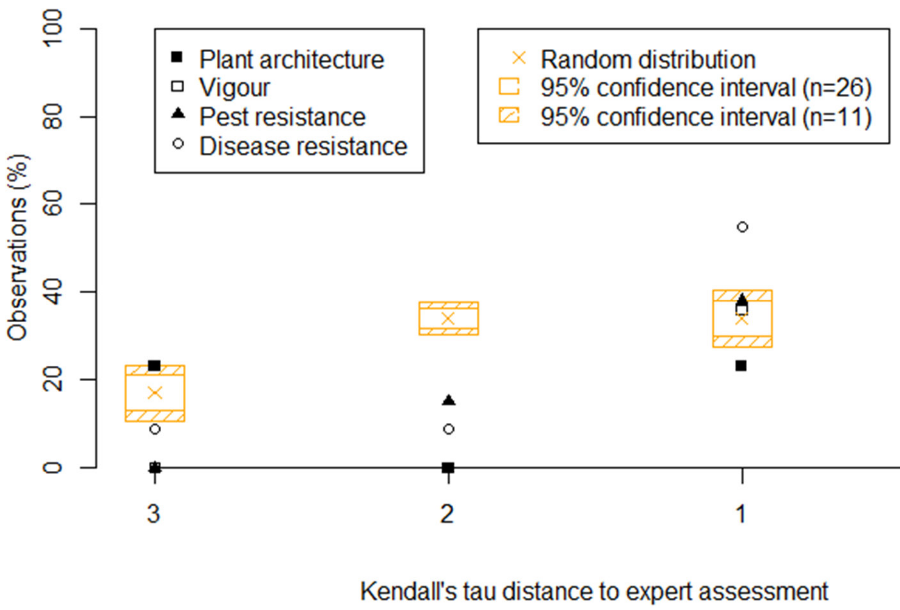


Figure 14: Frequencies of Kendall's tau distance of farmer trial observations to the expert assessment, including the confidence interval around a hypothetical random distribution. Validity of observation increases towards the right.

In Figure 14, the shares of each τ value among all recorded observations is plotted. The arithmetical shares of a hypothetical random distribution are included, too ('x' symbol). With the exception of 'plant architecture', observations with a low τ of 0 or 1 were consistently more frequent than a random distribution would suggest, and, in return, observations with a τ of 2 or 3 were less frequent. Only for rankings on 'plant architecture', observations with $\tau = 1$ were less frequent than a random distribution would suggest, while observations with $\tau = 3$ were more frequent.

Two confidence intervals were constructed, based on both i) the observed variation in the shares of each τ value among all observations, and ii) the smallest and biggest underlying sample sizes (11 and 26 observations, respectively), and added to the random baseline values in Figure 14. It can be seen that the share of rankings on 'plant architecture' with $\tau = 3$, i.e. completely wrong observations, lies within the confidence interval ($n = 26$) of the random distribution. Therefore, the null hypothesis, that the (high) share of these observations is due to random error, may not be rejected. Explicitly, this means the unexpectedly high rate might be due to farmers stating random rankings, instead of being actually convinced by the wrong ranking. Similarly, while the shares of observations on 'pest resistance' and 'vigour' with $\tau = 1$ are higher than a random distribution would expect, these shares lie within the random baseline's confidence interval, and this tendency cannot be ruled out to be due to random variation. Yet, considering the confidence interval, it becomes evident that rankings on plant architecture with $\tau = 1$ are significantly ($\alpha = .95$) less common than a random distribution would expect, while rankings on disease resistance are more common.

All in all, rankings of high validity are more common than rankings of low validity. Rankings with maximum validity ($\tau = 0$) are consistently more common than would be explicable by a random distribution, and rankings with low validity ($\tau = 2$ or 3) are generally less common than a random distribution would allow for, even with participant numbers as small as 11. While the frequency of observed rankings on three out of four traits increases with increasing validity (decreasing τ), 'plant architecture' is an exception, with 23 % of the rankings being completely opposed to the expert assessment (however, 77 % of the rankings have $\tau = 0$ or 1).

The mean τ of observations on one trait can be taken as a measure of overall observation validity and observation easiness. Rankings on 'vigour' are, on average, highly valid. Observations of 'plant architecture' and 'pest resistance' are slightly less valid, and rankings on 'disease resistance' are, on average, least valid, but still satisfying with a mean τ of just 1.0. These results relate to the expected subjective difficulty in observing the traits: While 'vigour' can be assessed easily from a distance, both 'plant architecture' and 'pest resistance' require some closer looks to individual plants and leaves, which may also be somewhat more time-consuming. Lastly, the correct observation of diseases (or their absence), especially in early stages, demands more thorough scrutiny and background knowledge. Especially the lack of training and awareness about diseases may be suggested as a reason leading to the relatively lowest validity, i.e. highest degree of incorrect observations on ‘disease resistance’, confirming the trait-specific different degrees of capacity described by Bentley (1989).

3.3.1.2 Bradley-Terry modelling

Table 21 presents the results of BT model estimation, with the expert-assessed best variety ‘X’ as reference. For two traits, ‘plant architecture’ and ‘vigour’, the BT models create significant partitions between all three varieties, and the estimates have the expected minus sign. This means that the observer groups were able to identify and distinguish all three varieties in the correct order. It is not implied that every participant fully agreed with the expert, but that the information given by the group of observers as a whole is sufficiently concordant with the expert assessment to identify significant cuts in a BT model. Even though some observers may have stated differently, X is significantly ranked before Y, and Y is significantly ranked before Z.

For the two traits ‘pest resistance’ and ‘disease resistance’, the ranking of Y is not well distinguishable from X (at a significance level of $\alpha = .95$), and the BT models did not yield significant cuts. However, X and Z are still significantly ranked differently, and thus correctly distinguished by the observers in the trials. Hence, even if farmer groups ($n = 11$ and $n = 13$) were not able to distinguish the best from the second-best reliably, a group of observers, as small as 11 for ‘disease resistance’, can effectively distinguish the best from the worst.

Table 21: Model coefficients for five Bradley-Terry models of variety rankings in farmer activities, with 'winner' variety (X) as reference. Y and Z are the expert-assessed second- and third-best varieties, respectively.

		Estimate	Standard error	*z* value	*p*	
Vigour						
	Y	-2.117	0.616	-3.437	0.0006	***
	Z	-3.514	0.719	-4.886	1.03e-6	***
Plant architecture						
	Y	-0.786	0.349	-2.253	0.0243	*
	Z	-1.234	0.366	-3.374	0.0007	***
Pest resistance						
	Y	-0.732	0.514	-1.425	0.1541	
	Z	-1.842	0.593	-3.107	0.0019	**
Disease resistance						
	Y	-0.395	0.519	-0.761	0.4465	
	Z	-1.187	0.558	-2.129	0.0332	*

* p < 0.05
** p < 0.01
*** p < 0.001

Observer numbers: n (vigour) = 22, n (plant architecture) = 26, n (pest resistance) = 13, n (disease resistance) = 11

3.3.2 Reliability

Kendall’s *W* was assessed for all traits as a coefficient of inter-observer reliability and included in Table 20. For rankings on ‘vigour’, Kendall´s *W* was calculated as .676, a value indicating strong agreement among the observers and allowing high confidence in the correctness of the aggregated ranking (a bridge to validity), following the rule of thumb on Kendall´s *W* proposed by Schmidt (1997, Table 22). A high *W* is reasonable, given that all observations have a τ value of 1 or 0.

From the rankings on ‘plant architecture’, Kendall´s *W* of .183 was generated, indicating very weak to weak agreement among observers, and thus very low confidence in the ranking. This is because 23 % of the observers gave a ranking opposed to the expert standard. Even as the agreement among observers is relatively low, $p < 0.01$ nonetheless indicates that the null hypothesis of no agreement can be rejected (i.e. the rankings are, explicitly, not randomly distributed).

Rankings on ‘pest resistance’ yield Kendall´s *W* of .337, meaning weak agreement and low confidence in the correctness of rankings. However, with the *W* test’s $p < .05$, the null hypothesis of no agreement can be rejected, and there is a visible tendency in the rankings (cf. Figure 14).

Rankings on ‘disease resistance’ result in Kendall’s *W* of .174, which may be interpreted as very low to low agreement and very low confidence in the overall ranking. However, given the small sample size of 11, $p = .148$ does not allow rejection of the null hypothesis. Hypothetically, if the exact same distribution of rankings were given, but data volume was doubled (n=22), *W* would still be .174, but $p < .05$. Under the given circumstances and at reasonable significance levels, however, no agreement at all among observers should be assumed.

Table 22: Proposal by Schmidt (1997) for the interpretation of Kendall’s *W*

W	**Interpretation**	**Confidence in ranks**
.1	Very weak agreement	None
.3	Weak agreement	Low
.5	Moderate agreement	Fair
.7	Strong agreement	High
.9	Unusually strong agreement	Very high

In summary, there is strong agreement among the observers on the ranking of varieties when asked about the plants’ ‘vigour’, low levels of agreement on ‘plant architecture’ and ‘pest resistance’, and no agreement could be confirmed for rankings on ‘disease resistance’. However, with increasing participant numbers, the observations on all traits present a satisfying level of reliability. This means, with any $W > 0$, a tendency in the observers´ rankings can be detected, and the distribution of observations is essentially non-random. Even low levels of agreement, as with observations on ‘disease resistance’, are sufficient to reliably detect significant differences between varieties, provided there is a minimum number of observations.

3.3.3 Conclusions

There is no common metric for accuracy, which rather needs to be discussed by looking both at a measure's validity and reliability. Two things can be concluded about farmers' observations in CCI: Firstly, the distribution of ranking patterns is far from random, and for all four pre-harvest traits, much more observations are on the good side than on the bad side. Random variation due to small sample size does not explain this distribution, so an advanced degree of overall validity can be confirmed for all traits.

Secondly, the level of agreement among the farmers (the measure's reliability) varies according to the specific trait, but is never nil. Reliability increases with increasing participant numbers, so overall, reliable results are a question of sample size.

Summarising the results presented in Tables 20 and 21, the accuracy of farmer observation as a method for data collection in CCI is very high for 'vigour', high for 'plant architecture' and 'pest resistance', and medium for 'disease resistance'. Nonetheless, it was shown for all four traits that, with a total number of just 11 observations, at least the best and the worst variety can be correctly distinguished by means of a BT model, as is implemented in CCI via ClimMob. Because observations are not random, larger numbers of observations lead to more refined models.

Less rankings may be necessary if training on critical observation capacities is enhanced: Particularly, evaluation of 'disease resistance' is an issue that requires facilitation or training, as was shown by the relatively high average τ to the expert assessment and the low agreement among the farmers. Weak observation capacity, as well as untimely evaluation, can lead to distorted results in CCI, and training elements on the evaluation of trials within specified traits may improve accuracy.

3.4 To question 3: Gender equity in CCI

3.4.1 Indicators of gender equity

3.4.1.1 Participation indicators

Indicator 1: Share of women participants

For a first appraisal of the gender-inclusiveness of CCI, a glance can be cast at the current gender ratio among participants. Of the 120 trial packages that were distributed for the *primera* season of 2014, only 98 were registered with an individual farmer, 18 of which were women. The share of individual farmer trials managed by women was thus 18 percent. However, many trials were registered with one responsible farmer, but carried out by farmer groups, namely community CIALs. There is evidence that male CIAL members disproportionately hold representative positions (Rural women focus group 2014), yet female membership in the groups averages to 42 percent (for Yoro region, Key informant Gómez 2014). This fact is likely to raise the total real share of women participants in CCI, yet it is still clearly below 50 percent.

Indicator 2: Evidence of facilitation for women participants

Given the pervasive discrimination of women in the Honduran society (UNDP 2011) and the low current share of women among CCI participants, it seems justified to specifically foster participation by women through facilitation. Such facilitation lies in the creation of both mixed-gender and, particularly, all-woman CIALs. Women's engagement in CIALs is encouraged (Classen et al. 2005, Key informant Gómez 2014), and in 2014, various CCI trials were carried out by 'women's research groups', i.e. all-woman CIALs. The creation of these groups was pursued by the NGO staff involved in CCI.

In addition, assuming that CCI is a regular CIAL activity, the involvement of women in mixed-gender CIALs also leads to enhanced participation of women in CCI on the long run:

> *"But, for example, the women. In a new CIAL, there is usually less participation and integration of the women than in an old CIAL. The women feel more empowered in the old CIALs, obviously due to the extent of time being organised."* (Key informant Gómez 2014)

While some women farmers fully manage their own productive plots, others are less involved in farming activities than their husbands: Some women only perform selected tasks like weeding, *"because for me it's difficult with the kids"*, as one woman CIAL member stated (Women CIAL members focus group 2014). Others perform all farming practices, except those including chemicals, i.e. fertiliser and plant protectives: *"No – they fumigate. I've only gone to sow. And to weed"* (Women CIAL members focus group 2014). In consequence, the women can be expected to have varying levels of farming capacity. The close collaboration with the local CCI facilitators is another measure of facilitation for any person with comparatively less farming expertise, thus women may especially benefit from this strategy.

Indicator 3: Evidence of women's empowerment through participation

The CCI methodology promotes gender equity by generally empowering women to adopt stronger positions in the community and in household decision making. This is likely to happen through capacity building. Many participants emphasised the personal learning brought along by participating in CCI. Referring generally to farming research by mixed-gender CIALs, including CCI, key informant Gómez (2014) explained:

> *"The community culture is: 'Well, women do not farm.' It is the man who farms. It is the man who has these abilities. Who can talk about the crop, about this, about diseases. So, to break this taboo, the women had to participate in outdoor activities, get to know the diseases, evaluate trials. And this way they showed that the women are able to know things just like the men, they just need to be exposed to this. [...] they had to find these spaces. But when they had them, the men realised that the women could do just as well, the same work as them. Therefore, they had more respect for the women's work."*

and

> *"we have seen that the men are somewhat more sensitive, [...] they are more open to collaborate in activities which are not within the traditional roles men have."*

As can be seen, there is evidence that shared research activities, involving farmers of both genders, strengthen women's position in society. In all focus group discussions, as well as at the farmer trial evaluation activities (cf. section 2.3.4), the author observed that group leadership, and the resulting confidence to speak out, was less influenced by gender or age, than rather by the degree of agricultural expertise. If a female lag in farming experience is assumed (see above), then evening out these gender-specific differences in agronomic capacity via involvement in CCI may empower women in the rural society.

The same is true for all-woman research groups. The capacity building empowers women to an exchange of expertise with their husbands at eye-level: *"Yes, one benefits, because you can tell your husband what you've learned, for example"* (Women CIAL members focus group 2014). By women farmers' participation in the trials, strict attributions of gender roles are weakened, and women's positions both within the family and within the community are strengthened.

Lastly, much of these observations are true even when CCI trials are not carried out by CIALs, but by individual farmers. The acquisition of agricultural expertise by women farmers is likely to lead to social recognition and increased respect for women's abilities, and the personal capacity building strengthens women's position towards their husbands and other household and community members.

3.4.1.2 Evaluation indicators

Indicator 4: Evidence of gender-neutral variety preferences

Gender-specific variety preferences can have strong implications for the process design, because this means that not any farmers' variety selection may actually represent the respective farming household's interests, and male farmers' selections could increase male privilege and gender inequity. The BT model of trait preferences, derived from the pairwise choice experiment (section 3.2.3.2), revealed no gender-specific preference scales for variety traits. Consequently, with more or less equal trait preferences, women and men are likely to have same variety preferences, as well.

A discussant at the rural women focus group discussion (2014) emphasised the gender-neutrality of variety preferences:

> *"So I believe that it must be equal. If he likes something, I must like it too, and if I like something, so does he. [...] Yes, we agree. So the experiment was done, we came to an agreement, and well - excellent."*

Although many studies in different contexts provide evidence that women and men, on average, have different varietal preferences (e.g. Defoer et al. 1997, Oakley & Momsen 2005), this finding cannot be taken for granted in all locations and for all crops. This study shows that the most vital traits of bean varieties for farmers in the study areas are 'yield', 'market value', 'plant architecture' and 'taste' (see section 3.2.4). Women farmers are a minority, but no exception in this sense. In the two focus group discussions conducted with all-woman groups, the prime importance of yield became clear: *"So we will keep the most productive bean for the productive plot", or:*

> *"That one, from the handful I sowed, there was almost no yield. And the other one, I sowed in just the same way, and it produced 25 pounds. Imagine that. So that means this is the very best bean"* (Rural women focus group 2014).

But market value was also emphasised:

> *"Because what is the point in harvesting some 30, 40 cargas* [a metric for 200 pound] *of bean, and we take it to the market, and there: 'Ah, we don't like these beans, because…' […] The market price - that is the best."* (Rural women focus group 2014)

For the farmers interviewed in the Women CIAL members focus group (2014), located in a remote area where bean is not being traded, market value had no importance. They, however, stressed yield and taste as their two most important selection criteria. It is difficult to detect reliably whether women consciously or unconsciously submit to male concepts of variety preference, especially given the fact that many CIAL leaders and most NGO facilitators are men. Nonetheless, reversely, there is no evidence of gender-specific variety preferences, either.

Indicator 5: Evidence of intra-household negotiation/agreement on variety selection

Negotiation between spouses about varieties and farm planning requires two conditions: Firstly, both partners generally need to have a say in the farm planning, and secondly, both partners need to have knowledge about available seed options. In practice, it was seen that women farmers and farmers' wives have a large variety of degrees and different kinds of influence on the household's variety choice.

For both conditions of intra-household negotiation, there is considerable variation, and there is evidence for both male, female, and shared decision-making on variety selection. One woman, for example, who does not participate in her husband's farming due to child-rearing duties, is willing to accept *"whatever they bring"* (Women CIAL members focus group 2014). Another women regularly asks her husband to plant certain varieties, thus initiating a process of intra-household negotiation:

> *"He brings me the beans. Look, I tell him, these beans are tasty. Bring me more of these, I tell him."*
>
> *"I do not know if that is common for everyone, but in my case, yes, I tell him: 'Sow that one because that one I like'."* (Rural women focus group 2014)

At the other end of the range, there are women farmers and women CIAL leaders who make autonomous farming decisions.

The degree of knowledge about existing variety options varies just as much: While some women merely distinguish black and red beans, others show very intricate knowledge about a large number of varieties. Various women farmers mentioned managing their own personal plot and extensively justified their variety choices and planning (Rural women focus group 2014, Women CIAL members focus group 2014). While the knowledge about existing varietal diversity is a precondition for both spouses to engage in negotiation about variety selection, this may not happen by default, if both farmers manage a personal plot. However, in the context of the inequitable asset ownership typical for Honduras (Deere et al. 2010), this is an uncommon situation. In summary, agronomic capacity and knowledge about varieties empowers women to negotiate variety selection. Yet, all in all, actual evidence about intra-household negotiation on variety selection is rather weak and anecdotal.

3.4.2 Conclusion

In conclusion, it is fair to say that CCI promotes gender equity by pursuing gender-inclusive participation, principally by building women's agricultural capacity. Currently, this takes place mainly through mixed-gender and all-woman CIAL groups. Both are powerful tools to encourage women to engage in agricultural production and innovation, and thus generally empower women in the rural community. It must be said that the effects of women's empowerment can be expected to be much lower in absence of these groups. In an upscaled CCI with independent, individual participants, it will be hard to involve women beyond a minority of autonomous women farmers with an own plot.

Women assume different roles in relation to crop production, from housewives who never participate in farming, to occasional engagement in the family's farming, to being local lead farmers. This entails differences in agricultural capacity and, on average, a structural lag to male farmers. While women's participation in CCI is still low, it is directly encouraged and facilitated by the creation of women's research groups. The capacity building promoted by carrying out a trial also empowers women to further engage in agricultural innovation, and generally strengthens their position in decision-making on the family's farming, as well as their position in the rural society.

Evidence on gender-inclusiveness of the variety evaluation is less clear. Variety preferences seem to be sufficiently similar across genders, which means the choice of crop attributes for the evaluation represents the interests of farmers of both genders. With equal preferences, it can be assumed that the variety evaluations of the predominantly male participants represent their spouses' preferences adequately. Since 'male' evaluations and 'female' evaluations follow the same preferences, there is no reason to believe the male majority among participants leads to 'male' results of CCI, favouring men's interests over women's.

While this finding may be true for the totality of farmers, within households, a non-farming woman may still have different seed preferences than her farming husband. It is clear that the agronomic capacity building of rural women via CCI research groups, including housewives, facilitates intra-household negotiation about the choice of variety for the family farm, and thus promotes gender equity. Women may be particularly empowered by CCI when a project focuses on a homegarden crop, and thus addresses the cropping domain typically ascribed to women.

3.5 To question 4: Motivation of farmers to participate in CCI

3.5.1 Main incentives

Continuous, positive impact of the new varieties

When asked whether the interviewees wanted to continue participating in the trials, 100 percent of the respondents answered yes, sometimes expressing strong enthusiasm. Everybody mentioned having benefitted from participating. Without being asked specifically, eight farmers (22 %) spontaneously stated having preserved harvested grain of at least one variety, in order to increase seed quantity and keep testing the variety/varieties under different weather conditions, with the final objective of maintaining and adopting a preferred variety to the production plot. A few participants were preparing to replicate the entire trial, including all three varieties, using seed from their own first trial's harvest in the *postrera* season of 2014, in order to perform the evaluation in the typically drier *primera* season of 2015, to obtain a better idea of the varieties' behaviour, and then decide on which variety to maintain. The varieties provided with the trials were referred to by many interviewees as "excellent" or "fantastic", and from this observation, it may well be assumed that more than the eight farmers mentioned above have preserved seed for augmentation.

There was considerable mention of seemingly intrinsic motives, like "I like experimentation". One CIAL member explained: *"Investigation is in our blood. I like it, if I don´t investigate, I´ll stay behind."* Nevertheless, most respondents seemed to have a clear idea about CCI's objective and potential, tangible outcome, and stressed the prospect of an improved livelihood, either through the access to better varieties or mediated by the learning experience. *"I do it to improve, to grow, to sow and harvest more"*, said one farmer. Motivation is thus largely rational and extrinsic. As a reason for participating, there was frequent mentioning of a desire for better varieties, *"to improve our varieties"*, as one participant puts it, or *"to adapt the agriculture to the zone"*. Eventually, it was said that this could *"improve our nutrition and improve our yields"*, and *"avoid to have to buy seeds"*. Thus, the pursuit of improved livelihood was a strong motive. One farmer explicitly stated that his goal was "food sovereignty", another one stressed he was seeking *the "security that what you are sowing will give you a result"*, and to *"sow without any fear, or risk, of losing [the harvest]"* (Palmichal focus group 2014).

Community development

Several respondents mentioned they were pursuing community development and stressed the 'spillover' effect of their, or the local CIAL's involvement, by linking the arrival of new varieties to the community to capacity development beyond the participating farmers, and to economic development for the whole community due to the potential spread of the adapted varieties. *"This is our responsibility as CIAL",* as one participant expressed, and another one stated that *"the investigation is for the whole community"*. Various interviewees recommended involving more members of the community in the trials, and one PRR field promoter mentioned that the trials generated much interest, causing *"many people"* in the communities to want to participate. He and others pointed out that the CCI participants share their experience with the wider community.

CIAL members act as custodian farmers to their communities, providing seed and agricultural advice (Classen et al. 2005, Sandoval et al. 2005, Reyes 2011). Several participants mentioned routinely borrowing or selling seed to neighbours and even people from neighbouring communities (Rural women focus group 2014), and pursuing the release of new varieties. In consequence, if CCI introduces new, locally adapted varieties to its participants, then, after a time lag, at least parts of the community will enjoy the same benefits. A spillover effect of the new varieties, contributing to general economic development or securing livelihoods, is likely, and Reyes (2011) shows that there is trade of the varieties between CIAL members and non-members. Albeit lower than among CIAL members in relative terms, adoption of new varieties by non-members is substantial in absolute numbers. Because CIAL members typically form a minority within a community, adoption of new varieties by non-members can have a strong effect on the local production context.

Capacity building

The capacity building mediated by participating in research about crop varieties can be identified as the most important output and incentive for the farmers. It is difficult to distinguish between lessons learnt because of CIAL involvement in general, and the CCI trials specifically, but "learning", especially about disease and pest management, was cited by virtually all respondents as a key feature to their motivation, for rational reasons: Various participants established the causal chain of learning experiences, improving cultivation, and eventually harvesting higher yields and higher-quality produce, achieving higher income. Statements like "*I participate to learn*", *"The greatest benefit is the learning experience"* or *"Every trial brings along new knowledge"* were pervasive, yet often linked to the prospected positive impact on production and livelihood: *"I participate to get more knowledge, more ideas, and to improve my cultivation"*, as one farmer explained.

Researchers emphasise that strengthening human capital, i.e. enhancing rural people's knowledge base and problem-solving capacities can initiate a continuous process of innovation, and a stronger and longer-lasting impact on rural development than just involving farmers in technology development via participatory research (Johnson et al. 2003, Sumberg et al. 2003, Classen et al. 2005). In this sense, the acquisition of cultivation and experimentation skills by farmers who participate in trials was perceived by themselves as an empowering strategy to cope with present and future challenges.

Indeed, empirical findings show that farmers are effectively empowered by participation in CIAL research: Classen et al. (2005) and Sandoval et al. (2005) found that CIAL members in Honduras and Colombia had higher levels of agronomic skill, had changed their way of production more often than non-members, were more likely to try out new crops and farming practices, were better enabled to identify problems and to find solutions, and were significantly less affected by food insecurity. Farmers in Palmichal confirmed that they were reaching higher yields and using less inputs since they began investigating (Palmichal focus group 2014). Key informant Gómez (2014) also asserted that the participation in variety trials can initiate a process of innovation, "not only at the level of varieties, but also of other practices". Given these observations from their own or their colleagues' experience, participants are strongly incentivised by the learning the trials bring along, and the entailed improvements in livelihood.

Social recognition

Lastly, the increased social status within the community may also play a role. CIAL investigators are perceived as agricultural experts and often hold important positions within the community (Classen et al. 2005, Sandoval et al. 2005). The repeated mentioning of the "responsibility" the CIAL investigators have towards their community can be seen as an indicator of their increased social prestige. Although CCI is not necessarily meant to rely on CIAL infrastructure, an investigating farmer may still be expected to benefit from peer recognition as a more experienced farmer, especially if CCI trials lead to the dissemination of new variety seed within the community.

3.5.2 Metrics of motivation

30 CCI participants rated seven different hypothetical reasons for participation, in terms of the strength of their personal agreement. For the metric conversion, see section 2.2.4. The results are presented in Table 23 and visualised in Figure 15, and subsequently discussed in order of importance.

Table 23: CCI participants' agreement with suggested reasons for participating. The presented values are derived from conversions of five verbal answer options to an integral 5-point-scale from -2 (no importance at all) to +2 (very important).

Reason for participation: I participate in the trials…	**Mean**	**SD**	**n[1]**
…because participating is interesting for me.	1.70	0.47	30
…to contribute to scientific research.	1.53	0.57	30
…to interact with the technicians.	1.07	1.08	30
…to be in touch with the community.	0.90	1.24	30
…to help the technicians get their work done.	0.69	1.42	29
…because I expect something in return from the technicians.	0.32	1.70	28
…to pass my free time.	-1.47	0.94	30

[1] **Any difference to the total interview number of 30 is due to non-response**

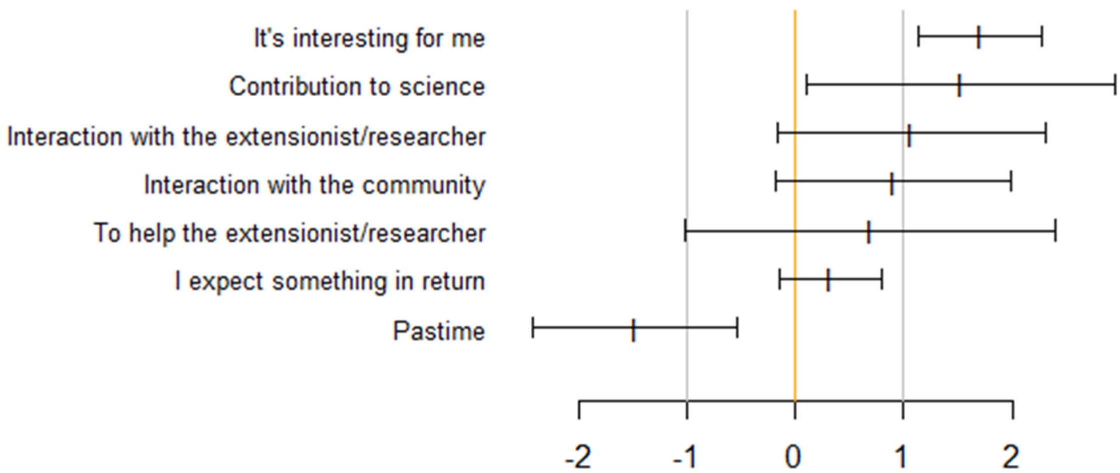


Figure 15: CCI participants' motivation for participating in the trials. Mean values are plotted with standard deviation whiskers (n = 28/29/30, cf. Table 23). A value of -2 means no importance at all, and +2 means "very important".

Personal interest

From looking at the values in Table 23, it is obvious that there is strong consent about participation being interesting, and that this is perceived as the overall most important reason for participation. 21 out of 30 respondents rated personal interest a 'very important' motive, with the other nine calling it 'somewhat important'. This finding reflects the prime importance of learning and capacity building which participants attribute to their involvement in the CCI trials, or to CIAL membership in general. Although no respective question was included in the questionnaire, it may be assumed that the answer 'participating is interesting for me' encompasses the farmers' anticipation of tangible benefits from participating. To the interviewees, 'interesting', hence, may basically mean *useful*, by enhancing their knowledge base on solutions and agricultural options.

Contributing to scientific knowledge generation

Contributing to scientific research was deemed an important reason to get engaged in the trials, which probably reflects the CIAL members' understanding of the benefits derived from prior projects. This concurs with the observations of Albuquerque et al. (2010) in an ethnobotanical study in Brazil, who found that a general belief in research, i.e. the general perception that the study "could be of benefit to science and the community", was the second-most important motive for the people to participate. It also matches many participants' claim that the research they are involved is meant to serve the community and farming households beyond the participating ones.

Interacting with the technicians

When asked about the importance of interacting with the technicians (the NGO field workers and extensionists assisting the CIAL research and implementing CCI), there was varying agreement. Although there was broad consent about interaction with the technicians being relevant and useful, many respondents stated that this was not a relevant motive for participating in the trials. However, various interviewees affirmed that it was useful to maintain close relations with the technicians, because *"that way I can call him quickly for some information"*, or *"so you can ask them when a disease appears"*. Two respondents claimed that the technicians' advice would actually be better, if trust was built.

Being in touch with the community

Despite strong variation across respondents, on average, interaction with the community was considered a fairly important reason to engage in the trials. Many respondents stressed the fact that exchange between neighbours is beneficial to all, that they learnt much from each other, and that the joint learning along the process was more effective than individual learning would be, or even that *"you do not learn alone."*

In this context, many participants also stressed the multiplier and motivation effect the CIAL members' activities have on other members of the community. For example, one respondent explained, *"There are producers who say that all varieties are the same, and just have different names. When they see the trials, they notice they are wrong!"*

The social capital created by the interaction among community members as well as with external NGO staff was hence acknowledged by many interviewees as an important incentive for their involvement. Classen et al. (2005) and Sandoval et al. (2005) emphasise and provide evidence that social capital building is a key benefit of CIAL work, by minimising risk and improving trust and cooperation even beyond the agricultural sector. Across the world, environmental citizen science projects are shown to positively influence social capital, empower communities beyond the participants for local engagement, and thus lead to more sustainable communities (Conrad & Hilchey 2011).

Helping the technicians get their work done

Although nine out of 29 interviewees deemed it 'very important', the wish to help technicians with their job was, overall, a minor intrinsic motive for participation. Its average importance lies between 'neutral' and 'somewhat important' (0.69). Interestingly, in a study on rural people's motivation to engage in participatory research, Albuquerque et al. (2010) found this motive to be the one most important reason given by the study participants. However, in that study, the residents had never taken part in a research project before, and participation was limited to answering an interview. Not surprisingly, it was hard for the local people to anticipate any other motive, whereas the Honduran farmers, retrospectively, view the benefits and much more prominent motives than the (still somewhat important) wish to help the technicians or researchers. Among the respondents who called helping a 'very important' or 'somewhat important' motive, many stressed that they are happy to give the technicians something back for all the support they had received before. The inherent mutuality and interdependency of the farmers' and technicians' work was stressed. Two interviewees even expressed their concern that the technicians might stop support to the community if the members did no effort to help them. Others stressed that their cooperativity was a question of honour, e.g. *"we collaborate with them, because they support us"*. Nonetheless, six interviewees stated that helping the technicians did not motivate them at all. As one farmer put it: *"They have their job, and we have ours."*

Expecting something in return from the technicians

The importance of farmers' expectations from the technicians is highly variable, and surprisingly low on average. 17 out of 28 interviewees claimed that expecting something in return from the technicians was 'very important or 'somewhat important' to them. However, ten farmers mentioned that expectations from the technicians were of no significance to them. A common statement was "I participate because I want to, not because I expect anything". Farmers then emphasised the relevance of personal learning, something they could not expect the technicians to actively provide them with. On the other hand, those respondents who did consider their expectations to be a somewhat, or very important motive (the majority), consistently specified they were expecting knowledge, teachings, guidance or agronomic advice about pests, diseases, fertilising and cultivation techniques.

This diametrical opposition is remarkable: As it appears, there is dissent about the origin of knowledge and innovation and the extensionists' role, possibly due to different levels of knowledge and experience among the farmers. One long-serving farmer-researcher pointed out that knowledge generation is a group process, and that CIAL work, including CCI, causes *joint* learning with the technicians. Many participants made similar statements, but others mentioned the technicians were able to share ideas that the farmers would not have, and should guide or teach the latter. Nonetheless, there was overall agreement that expectations from the technicians were not a main motive for getting involved, but rather resulted inherently.

Only one interviewee mentioned expecting the technicians to report back on results: *"Just that one trial is not enough, what matters is the overall results from all trials"*. The low importance given to this reason might be attributable to prior experiences of experiential learning, in which final formal results are of less importance than the individual learning process based on observation and participation.

Trials as a pastime activity

The concept of participating in CCI trials as a 'pastime' activity was strongly rejected by most interviewees, although two farmers gave positive responses, adding that they derived pleasure from the process and enjoyed taking care of the trial. The other participants, however, generally insisted on that the activity was to be taken seriously and served other purposes than just to pass free time. Some mentioned that, when it comes to passing time, they would rather play football or play cards. Jacob van Etten (pers. comm.) suggested farmer might emphasise the 'serious' nature of the trials in order to comply with expectations they assume the project implementers have. It may in fact be assumed that participation is not a dull activity or causes drudgery, mainly due to group interaction and personal learning (see previous sections). Richards (1989) showed that farmers experimented with varietal diversity of crops just for fun. However, as an explicit reason influencing the motivation to participate in the context of this study, intrinsic motives of leisure and fun are likely to be minor, also because this topic has not been brought up by any interviewee.

3.5.3 Conclusions

At this point, the research questions specified in section 1.6 (4) can be answered, the third of which will be discussed in the section following hereafter:

- What motives drive CCI participants' willingness to engage in the trials?
- What incentives are most effective in motivating participation?
- How can these incentives be enhanced in CCI?

Applying the framework developed by Batson et al. (2002) to this study, motivation to participate in CCI can be attributed to egoistic and collectivistic motives: The farmers' motivation is rationally driven by the pursuit of improved livelihood options and increased food security, for themselves and their immediate community. There is evidence of some intrinsic motivation, but farmers are primarily extrinsically motivated to participate, by the prospect of increased and sustained agricultural production. Three pivotal incentives for the involvement in CCI can be identified: Acquisition of skills and knowledge (capacity building), access to the new varieties, and the generation of social capital.

In Figure 16, the main motivation structure for CCI is shown in brief: Farmers participate because they view CCI as a promising strategy to accomplish their goal of livelihood and food security, and they are incentivised by three projected impacts of CCI which are believed to facilitate the accomplishment of this goal. The pursuit of social recognition is deliberately left out in the shown structure. It is considered an important, but separate motive; yet for this motive, capacity building is the key incentive for involvement, too.

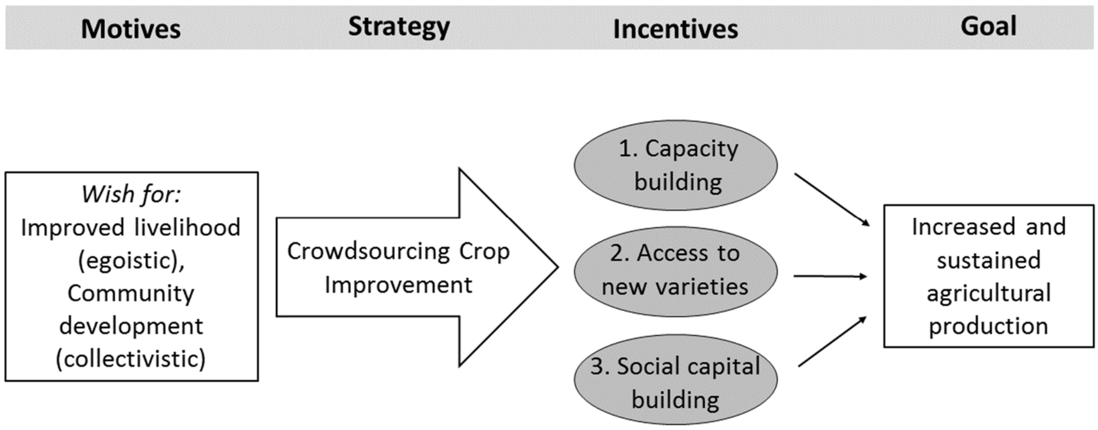


Figure 16: Main motivation structure for participation in CCI

The findings are consistent with evidence by Rotman et al. (2012), who found that initial engagement in citizen science generally rests on egoistic motivation, and the strive for personal learning as well as sheer fun are the most important reasons. While personal learning is perceived as crucial by CCI participants, too, fun (‘pastime activity’) was largely rejected as a motivation, probably reflecting the vital role of agricultural production in CCI participants’ lives. In a study involving contributors to 19 citizen science projects, Shashidharan & Shaikh (n.y.) found that personal learning was the most often cited reason for participation, followed by the contribution to science and the community, and the “interaction with new people”, i.e., social capital building. Both studies confirm that egoistic motives are most effective in fostering participation, followed by collectivistic and altruistic motives (community development), mainly after impacts of the project have been observed.

The marked boundary between volunteers in other citizen science projects and the farmers in CCI with respect to the relevance of leisure goals emphasises the particular characteristics of crowdsourcing with farmers, and has certain implications for project management: In contrast to most citizen science projects, generating fun as an incentive will play a negligible role for implementers. The curiosity about the varieties’ names, allowing comparison of their performance with other farmers' trials, is a driver of *persistent* participation, and is ensured by making the randomisation blind.

On the other hand, the importance of a tangible, livelihood-related benefit to participants (getting access to new varieties) is unique to CCI, and should not be overlooked. This means that, in order to maintain this incentive in reach, CCI implementers are required to ensure farmers get access to i) the information about which varieties are most suited for their context, and ii) the information about where to access, e.g. to borrow or swap some seed of that respective variety, in a timely manner and an appropriate communication channel.

3.5.4 Recommendations

With the aim of involving as many farmers as possible in CCI, the incentive structure may be adapted to revolve around these three pillars:

- Capacity building,
- social capital building, and
- social recognition.

'Access to new varieties' (cf. Figure 16) is an incentive inherent to CCI, and an exposed visibility of the new varieties' comparative advantage can be expected to further increase interest among non-participants. As stated above, implementers must facilitate this access to the fullest extent possible, e.g. by stocking community seed banks and helping to build local enterprises for seed production. In practice, enhancing elements of capacity building will be the most promising strategy for project implementers to reach and motivate a high number of farmers. It is important to remember that both agronomic skills and knowledge on one side, as well as the methodological empowerment to experimentation on the other, are capacities sought after by farmers. An initial workshop for CCI participants, focussing on the establishment of trials and collection of data will necessarily include some training, e.g. in disease recognition, and thus serve both purposes.

Social recognition and prestige can play a dominant role in innovation and technology adoption, and its relevance as an incentive should not be underestimated (Henrich 2001). Sandoval et al. (2005) provide evidence that experimenting farmers are recognised by their community as agricultural experts and good representatives of their community, and are regarded as suitable for representation and leadership roles. Hence, agricultural expertise and social prestige are strongly connected in the social context of this study.

And lastly, Rotman et al. (2012) show that volunteers in citizen science are incentivised to contribute by the social recognition conveyed by invitations to scientific trainings and workshops.

As a consequence, organising once-only training events (as opposed to the recurring, and potentially deterrent, commitment for CIAL members) on agricultural topics related to CCI as a reward for participation can be expected to incentivise farmers: The training is likely to enhance both the capacity building and the social prestige connected with participation, as well as social capital building due to the interaction with other farmers and the researchers / extensionists. These activities should be advertised as an offer and a reward, and participation in CCI should not depend on participating in them, to avoid the exclusion of farmers with heavy workload or other responsibilities. Whoever implements the CCI project will need to take responsibility for the organisation of the events, and in the region of this study, they could be carried out by NGO technicians, field facilitators, or experienced CIAL members as 'local CCI facilitators'. A structure for the training activities is proposed in table 24.

Table 24: Proposed agenda for training events alongside CCI for facilitation of capacity building and generation of social capital

Activity	**Time**	**Contents**		**Attendance compulsory**
		CCI-specific	***Agronomic knowledge***	
Inception workshop	Four weeks before sowing date	Distribution of CCI trials and registration of participants How to set up a trial and use the evaluation card	Optimal preparation of a bean plot Avoiding soil-borne diseases	No *(However, there is no alternative distribution pathway for CCI trial packages established yet)*
Mid-term meeting	30-40 days after sowing	Exchange of experiences Clarification of questions	Identification of common diseases and pests	No
Conclusion workshop	After the data from most trials has been fed back and analysed, six weeks after harvest	Feedback and discussion of overall results Names of varieties each farmer had received	Selection of seeds for sowing Seed storage	No

3.6 To question 5: Upscaling of local experiences

3.6.1 Methodological obstacles

3.6.1.1 Farmer level: Difficulties performing the CCI process

Trial set-up and cultivation

No participants seemed to have technical difficulties with setting up the trials, indicating that the trial design is sufficiently simple. In all observed trials, the three varieties were planted next to each other, in six rows of eight meters length, as requested. There was substantial variation with respect to slope, weed management and distance between rows, yet this variability is likely to reflect the diversity of environmental conditions and management styles practiced by the individual farmers, who had been encouraged to plant and manage the trials just as they were used to do with beans.

Some trials were placed right next to, or even centred within the productive plot, whereas other trials were located on a fallow, or even on a specific trial plot, close to the farmer's house. While setting up a trial at the productive plot will yield results applicable to larger scale on the plot later on, using a specific trial location may restrict the usefulness of the results for the farmer. A special trial plot may have particularly marginal or good soil conditions, and receive inadequately little, or much, attention and care and this way distort results.

It is important all varieties within one trial grow under equal weather conditions. While different harvest dates, taking account of different maturity speed of the varieties, are not critical, all seed must be sown at the same date. In practice, some trials were reported to have been sown in successive steps. This condition means the varieties under comparison face abiotic and biotic stressors, e.g. short dry spells, in different growth stages, and final rankings are distorted, possibly not representing the varieties' different qualities correctly.

Trial observation

After receiving their trial packages, including the seeds and the observation card, to many participants, the different steps of observation were not clear. Various participants mentioned filling the entire observation card on the same day. The observation is supposed to be carried out in three steps, and so should the card be filled in three steps: Early vegetative criteria ('vigour' and 'plant architecture'), biotic stress criteria ('pest resistance' and 'disease resistance') and post-harvest criteria ('yield', 'market value' and 'taste'). While it is feasible to memorise the respective ranking orders and fill the sheet all in one, after harvest, farmers' memories might be biased by the latest results: For example, the most yielding variety may then be falsely attributed highest pest resistance, etc. In this aspect, participants lacked guidance and capacity, hence clear guidelines on the evaluation card, as well as an initial capacity building around farmers' obligations in the CCI process may help to avoid such problems.

Furthermore, many participants showed and expressed difficulties in clearly distinguishing the variety traits. The mental divide between different aspects of a bean variety was not clear to all farmers: When, for instance, one of the three trial varieties showed good vegetative qualities, like a well-developed foliage and growth, many participants at the trial evaluation activities were inclined to attribute best pest and disease resistances to this variety without even checking for attacks. Though these outcomes are possible, a well-developed foliage being an indicator of environmental adaptation, it is wrong and misleading to strictly assume that one variety performs best in all evaluative criteria. Most farmers seem to have little difficulty in selecting which variety they like best overall, yet splitting the evaluation into distinct criteria and eventually accepting a different 'winner' per criterion was challenging for many CCI participants. In an initial workshop on CCI, new participants may practice evaluation with a 'dummy' trial, where a local facilitator can demonstrate the evaluation step by step, and show e.g. that a variety may have best growth habit, but worst pest resistance.

Lastly, deficits in agronomic knowledge posed a major constraint to correct evaluation, mainly of pests and diseases. Farmers in the research area generally refer to any discolourisation of leaves as *hielo* (Spanish for frost), and some specify the colour, calling damages 'white frost' or 'yellow frost' etc. In fact, changes in colour or texture of bean leaves can be caused by insects, microbiotic agents, or nutrient deficiency, so distinguishing pest and diseases attacks is, for the least, not intuitive. It is fair to assume that not all CCI participants had precise knowledge about pest and disease recognition when carrying out the evaluation, which distorts the results about the varieties. This constraint may be coped with methodologically in two ways: The accuracy of information output in CCI may be reduced by subsuming pest and disease resistances to one criterion, e.g. simply asking farmers to mark the varieties with most and least 'damage'. Alternatively, training for participants needs to be intensified. Knowledge about the five most important diseases and pests may be included into an initial CCI workshop, and farmers may be given a booklet or sheet that gives on-site assistance in the identification and distinction of pest and disease attacks.

3.6.1.2 Farmer level: Difficulties with the observation card

Illiteracy

According to the CIA World Factbook (CIA 2011), adult literacy rate in Honduras is 85 %. As urban-rural disparities in literacy are known for many countries (Eastwood & Lipton 2000, Zhang 2006), the literacy level among the resource-poor farmers may be expected to be lower. In the context of this study, the rate of illiteracy of a small sample was assessed to be 25 percent (see Table 25, this section). Moreover, literacy is hardly an absolute concept. While the majority of participants were able to read the brief instructions and questions on the card, even local facilitators presented relatively low fluency in reading of longer phrases. Fully illiterate participants depended on the presence and assistance of a local facilitator. In order to avoid the exclusion of illiterate farmers and keep facilitation requirements low, the observation card needs to be adapted, by adding illustrations of the evaluative criteria. An illustration of the high level state of the trait (e.g. well-developed foliage) may indicate the position the best variety is to be marked at, and vice versa. Generally, the need to read text should be avoided as much as possible by a pictorial design. Where this is not possible, illustrations may serve as reminder icons, the meaning of which can be explained at initial CCI workshops.

Phrasing

Various stakeholders mentioned the observation card was using complicated phrasing. For example, *¿Cuál variedad resiste mejor a plagas?* (Spanish for: Which variety is most resistant to pests?) was one question leading to much confusion among the CCI participants. While the research interest indeed lies in *resistance*, what farmers directly observe is *damage*, and speaking of resistance is an unfamiliar concept to many. Consequently, many participants were in doubt as to whether the question refers to the most, or the least attacked variety.

Along this line, at the farmer trial observation activities and other visits to CCI trials, it became clear that farmers do not use the term ‘vigour’, but rather refer to its observable elements - like ‘strong shoot’ or ‘nice foliage’. Untrained farmers usually did not know what was meant by ‘vigour’. In order to avoid this methodological obstacle, questions on the observation card should use as little words possible, and adhere to the phenomenological way farmers observe, i.e. 'Which variety is most resistant to pests?' should be replaced by 'Least pest damage', and 'Best foliage' should be used instead of 'Best vigour'.

Visual design

For analysis with ClimMob, it is important that CCI participants indicate exactly one variety as best, and a different one as worst. Screening observation cards and data compiled by the extensionists of PRR and FIPAH, various deviations from the intended way of usage could be observed. These include: Farmers marking the same variety as best and worst (e.g. A/A), marking two varieties for a single question (e.g. AB/C), failing to mark one side of the question (e.g. A/-) or adding their local variety as 'D' when it was perceived to be worse, or superior to the trial varieties (e.g. A/D). All of these deviations turn the data useless, and can be avoided to a certain extent by means of an improved visual design.

3.6.1.3 Project level: Restricted coverage

Going beyond CIALs

Various stakeholders estimated that roughly 20 percent of the farming population may realistically be involved in CCI in any community (e.g. Key informant Gómez 2014, Key informant Mejía 2014). Yet, some minimum form of access to the farmers is needed in order to identify suitable and interested participants and distribute trial packages. Historically, the two NGOs' cooperation with CIALs and local lead farmers fulfilled the role of an access bridge for CCI to the farming population, being in place prior to the introduction of CCI. Specific training for trial setup was relatively easy to implement with the existing groups. Involving independent farmers, however, has been limited, due to the difficulty of facilitation and training, which represented a threshold to the implementing NGOs.

Key informant Mejía (2014) suggested involving independent farmers in 'promotional tours' for CCI. At such tours, few weeks before the regular planting season, in consultation with community leaders, interested farmers might be invited to assist a brief 'seed innovation workshop', where Bioversity's educational videos about CCI can be screened, and new participants may register and receive trial packages. While this approach requires some cooperation with community leaders and probably still excludes the most remote (geographically or socially marginalised) farmers, it is conceivable in any area, and in absence of CIALs.

Similarly, Jacob van Etten (pers. comm.) advocates promoting CCI at agricultural events, like farmers' markets or seed fairs. Such events are rare, but a regular element of rural life in many parts of Central America, and are important showcases for seed exchange and rural innovation. Like in the promotional tours, a CCI stand could present educational videos, farmers could receive a trial packages and register with their telephone number for data feedback. Bioversity and local partners in Honduras have involved various farmers in this way.

Beyond CIALs, any grass-root organisation may serve as an access point for CCI. NGO extensionists suggest contacting rural credit and farming cooperatives (Key informant Gómez 2014), as well as collaborating with other NGOs (Key informant Mejía 2014), to extend the project's reach. In fact, it could be observed that carrying out a first trial cycle within a group empowered farmers to successfully carry out subsequent trials individually. As a first step, the implementing NGO may need to assist a group of farmers in their joint endeavour of realising a CCI trial, yet in the following season, the – thus trained - group members might be interested in receiving an individual trial, to test varieties on their own farm. In theory, any rural group can fulfil the role of providing the base structure for CCI, even religious groups gathering for a joint CCI trial are imaginable. Identifying and training local facilitators as multipliers for CCI is key for involving new groups and organisations.

Key informant José Jiménez (2014) argues for cooperating with the extension services of national agricultural ministries or national agricultural research systems (NARS), since these services operate within a nation-wide network, covering all regions. Many Central American NARS distribute generic quality seed of improved varieties with the objective of increasing small-scale farmers' yields and safeguarding food security. Using these established, extensive distribution channels for a regional or nation-wide CCI project, a high number of farmers may be reached. If decision-makers can be convinced, this strategy may be most promising for rapid, massive upscaling.

Mobile phone usage

Using participants' mobile phones for data collection and information feedback may dramatically reduce facilitation effort and enable involving much larger groups of participants. To explore the potential for this methodologic adaptation, 30 CCI participants were interviewed about their mobile phone usage habits and experiences (cf. section 2.3.1.3). Key results are shown in Table 25. Only two interviewees denied owning a mobile phone, corresponding to 7 percent of the answers. The rural population of Honduras generally uses pre-pay SIM cards, and airtime credit may be purchased at many small local shops, even in remote villages. Only one respondent stated never maintaining airtime on her phone, whereas the majority spends money on airtime credit sporadically, and twelve interviewees stated "always" having at least some airtime. So, although virtually all respondents regularly spend money on their phones, monthly spending is highly variable, and averages as little as 101 ± 86 Lempiras, less than five US dollars. In consequence, any system of data collection requiring farmers to actively provide information by sending messages or calling facilitators is inappropriate, given the fact that airtime credit tends to be a relatively scarce good. However, with 93 percent of the interviewees possessing and using a mobile phone, a phone-based system is realistic, as long as there is no cost involved for participants. Honduran mobile network providers allow customers to charge airtime credit to any phone, so charging a certain amount of credit to CCI participants' phones could be a quick and rewarding compensation for providing information. However, this recompense incentivises farmers to report observations even in absence of data, e.g. when a trial failed due to drought, and should therefore be avoided or used with great caution.

Nine interviewees (31%) from seven different communities mentioned their household, community or neighbourhood not being connected to electricity. This shortcoming mainly affects the highest settlements in altitude, due to the slow pace of electrification, spreading from power lines in the lowlands. The current condition results in telephones being uncharged often, *"sometimes half the week"*, as an interviewee in El Plantel (Victoria, Yoro) said. To charge their phones, rural dwellers usually 'go down' to lower communities or the nearest town, where some shops offer phone charging service for a few Lempiras, and it is not uncommon that one person carries in various phones for friends and family. It is due to this constraint that various interviewees expressed their concern against relying on mobile phones for data collection.

The absence or weakness of network coverage in remote areas, particularly the farming plots, where farmers pass a great part of their days, was also mentioned as a limitation. The poor supply with electricity and network coverage in rural areas does not make a mobile phone-based system impossible. Examples from Asia and Africa show how similar phone-based extension services can benefit the poor even in highly remote areas (Tall et al. 2014). Yet, additional measures may need to be taken in response to the specific constraints, like attributing additional phone numbers to one farmer (e.g. of spouse or children) and conforming to calling in afternoon hours, when the probability is highest to find the farmer in a settled area with network coverage.

The challenge of occasional lack of phone battery charge may be overcome in the near future with electric infrastructure development in most of the study sites, and with taking the situation into account in an appropriate way: CIAL members in El Plantel suggested that messaging was a better way of communicating than phone calls, since messages would still arrive with delay if a receiving phone was out of battery at the time the message was sent. Others recommended announcing calls by messages one or two days ahead, to increase the chance the phone would be charged and the owner be at a location with network availability.

Although only 25 percent (7 respondents) stated being illiterate or ‘almost illiterate’, actively using short message service (sms) is rather uncommon, with only nine respondents (32%) ever using sms, mainly in low frequencies of two to three messages per week. In fact, 61 percent of the interviewees (17 persons) stated never having sent a single message. The phones are predominantly used to make and receive phone calls, and all but one respondent, who expressed never buying any airtime, are accustomed to making calls. Most interviewees claimed to call in emergencies only, or to make no more than a few phone calls per week, and only six respondents (22%) expressed making calls on a (nearly) daily basis. When asked about the potential use of calls and messages for data collection in future CCI cycles, 68 percent of the interviewees (19 persons) preferred being called over receiving messages, while 25 percent (7 persons) expressed no preference, and only two respondents (7%) from the Yoro region stated preference for messages, for the reasons of battery charge and network scarcity mentioned above. The majority of CCI participants preferred calls because of the possibility to mutually ask questions, in order to clarify any issue in doubt. Many interviewees mentioned that calls would provide better mutual understanding, and transmit more information.

Illiteracy and the cost of answering messages, as opposed to answering a phone call, were also mentioned as reasons for preference. Automated voice calls, i.e. farmers verbally responding to a computer voice, save resources for the implementing body and avoid excluding illiterate farmers, however the opportunity to clarify questions is lost. A compromise may consist in collecting data via automatic calls, including a time frame where participants can leave comments or ask to be called to discuss an unclear issue.

Table 25: Most relevant variables of mobile phone usage of CCI participants

				% of n	**n [1]**
Research regions			4		
Municipalities			9		
Communities			17		
Age			46 ± 14*		30
Gender					30
	Women		2	***9 %***	
	Men		28	***91 %***	
No electricity			9	***31 %***	29
Phone possession			28	***93 %***	30
Monthly expenditure on phone (Lempiras)			101 ± 86*		26
Airtime credit maintenance					28
		Never	1	***4 %***	
		Almost never / Sometimes	15	***54 %***	
		Always	12	***43 %***	
Functions used					28
	Calls				
		Never	1	***4 %***	
		Almost never / two per week / three per week / several per week	21	***75 %***	
		Almost daily / Daily	6	***21 %***	
	Messages				
		Never	19	***68 %***	
		Few / Several per week	7	***25 %***	
		Almost daily / Daily	2	***7 %***	
Illiteracy			7	***25 %***	28
Preference of receiving calls or messages					28
	Calls		19	***68 %***	
	Messages		2	***7 %***	
	No preference		7	***25 %***	

[1] n = number of respondents. Varies because of leaving questions out at certain interviews for logical reasons (e.g. in case of the two respondents who did not own a phone), or due to time pressure at the moment of the interview.

*** ± standard deviation**

3.6.2 Conclusions

Two principal kinds of methodological obstacles were identified. Firstly, farmers face individual difficulties in participating in CCI at the current state. This, in turn, increases facilitation efforts for the implementing bodies, locks resources, and hinders upscaling. Secondly, inherent constraints to the methodology, like the reliance on regionally bound CIAL infrastructure and the underexploited potential of mobile phone technology, limit the implementation of CCI to a low number of participants.

Consequently, for upscaling the current design of CCI, two improvements are needed: Firstly, the individual facilitation by resource-restricted implementing organisms must be minimised, via a more intuitive and simple process design, initial capacity building for participating farmers, and collecting data by mobile phones. Secondly, the recruitment of participants must emancipate from CIAL structures. Local facilitators, i.e. renowned members of the rural communities taking responsibilities in CCI, are likely to play an important role in constructing a CCI system that complies with these conditions.

Farmers' capacity constraints, both in agronomic knowledge and about their roles and duties in CCI, were identified as important obstacles to an automatised, large-scale implementation of the methodology. Therefore, building participants' capacity and ensuring a good understanding of the methodology via an initial training workshop is suggested as a central strategy for reducing the requirement of facilitation and inducing automatisation of the CCI process. These workshops can be held by local facilitators, so organisations implementing CCI can focus on identifying and training the latter, who in turn promote and introduce the methodology to interested members of their communities.

Facilitation requirements can probably be strongly decreased by re-designing the observation card to make it usable for illiterate participants and to avoid incorrect usage. Adding important information like the suggested timing and concise instructions, avoiding complicated and ambiguous phrasing, adapting phrasing to the phenomenology of farmers' observations, as well as employing a generally suggestive and intuitive visual design will help to overcome farmer-level methodological obstacles.

Constructing a system of data collection and information feedback via mobile telephones is believed to be feasible with the target population of this study. A big majority of farmers is reachable by telephone at least at certain times, and constraints of battery charge in un-electrified communities can be overcome by announcing calls by message or voicemail and asking for alternative phone numbers, e.g. of neighbours or family members. However, data collection may be most efficient when local facilitators pick up the data from the participating farmers in their community, and report the data to the implementing extensionists via a reverse call[8]. Relying on local facilitators, however, may also bring along negative side effects, particularly the potential enhanced marginalisation of remote households or families with any conflict with the facilitator's social environment.

With respect to including more farmers, beyond CIAL members, various CCI stakeholders related to the big scope of involving other grass-root organisations and farmers' groups, as well as the potential of interacting with the governmental extension service. Promoting the methodology at seed fairs, farmers' markets and at agricultural stores can help reaching many potential participants, but is costly. If promotion is specifically targeted at identifying and involving local facilitators, the positive effects on participant number may be enhanced even more strongly. With setting appropriate incentives for opinion-leaders of rural community to engage as local CCI facilitators as a part-time activity, upscaling can be boosted.

3.6.3 Recommendations

Initial workshops for training and trial distribution

As was outlined before (section 3.5.3), training events before the planting of trials are incentivising participation due to the capacity building, but also necessary for ensuring data quality and data feedback. These events can also serve the distribution of trial packages and registration of participants, and generally provide attendees with a thorough induction to CCI. Participants should be enabled to set up a trial, observe plant attributes at the appropriate points in time, and fill the observation card in the appropriate way. A standardised procedure for the workshops will make it possible to leave them in the hands of local facilitators, whereby facilitation efforts 'trickle down' and the system's overall transaction costs are reduced. A structure for initial CCI workshops is proposed as follows:

Timing: Four weeks before the regular sowing season starts, so farmers can adapt their planning, e.g. avoid purchasing seed for the acreage the CCI trial will be sown in.

[8] free of charge for the person calling

Place: Implementing organism provides a central facility that can be reached by all invited farmers, like an NGO office, a community hall, etc. If it is feasible, e.g. by using irrigation, an example CCI trial should have been planted nearby, about one month ahead. If it is not possible, workshop attendees may plant an example trial together.

For the screening of an instructional video, a PC and a projector are useful.

Participants: About 20 participants, preferably at an even gender ratio. Farmers can get invited through different channels, e.g. by local facilitators, at promotional tours, at seed fairs, etc.

Procedure: 1. Screening of videos #1 and #2 of Bioversity's cycle of instructional and promotional video about CCI

2. Explanation of the methodology to farmers, focusing on the potential benefits and on participants' responsibilities

3. Visit nearby CCI trial to familiarise with the trial design

4. Practice observation and filling in the respective steps in the observation card, about plant attributes that may be evaluated at the time of workshop at the trial planted priorly (e.g. 'vigour', 'plant architecture', pest incidence)

5. Facilitators / extensionists give a practical lesson about an agronomic issue of relevance for participants, both for participating in CCI and for their own farming, for example: Disease recognition and management

6. Distribution of trial packages (including seed packages marked with A, B, or C and the individual trial ID, observation card, and Bioversity's CCI flyer for farmers) and registration of participants. Minimum information that must be inquired for the unique identification of participants:

Full name, name of spouse / father, village (community), district (regional adherence), telephone number

7. Giving a certificate of participation to every attendee: Honours farmers' efforts and serves as a reminder along the process cycle.

8. Joint snack / lunch

Redesigning the observation card

The observation card needs to be redesigned with three objectives in mind:

(i) Improve timing of observation by adding the respective information about evaluation steps (which attributes should be evaluated at what day after sowing),

(ii) Make CCI more accessible for illiterate farmers and less confusing for all participants, by reducing text and expressing the plant attributes by illustrations and icons, as well as shortening and simplifying phrasing,

(iii) Improve overall data quality by avoiding observation records that cannot enter the analysis, like double ticks, via a suggestive design of the response boxes.

Based on these recommendations, a visual designer has re-designed the observation card, and an excerpt is shown in Figure 17 in opposition to the previous design.

As can be seen, an instruction is included about the recommended day after sowing (*"Paso 2. A 45 días de la siembra"*, Spanish for: Step 2. At 45 days after sowing). Text is shortened down to minimum, adapting to the phenomenology of farmer observations (not 'resistance' is observed, but presence or absence of pest and disease damages). The individual plant attributes are visualised for illiterate farmers, who would still get an introduction at an initial CCI workshop. By the specific design of the response boxes (high- and low-level pairs are juxtaposed, circle only fits one letter), various possible errors may be avoided or reduced, namely double ticking (*AB/C*), evaluating only half (A/-), adding local control (A/D), or marking the same variety twice (A/A).

Preguntas sobre las plantas *Compare las tres variedades*	**Respuesta** Subraye solo una variedad por cada pregunta		
Cuál variedad tiene el mejor vigor	A	B	C
Cuál variedad tiene el peor vigor	A	B	C
Cuál variedad tiene el mejor porte	A	B	C
Cuál variedad tiene el peor porte	A	B	C
Cuál variedad resiste mejor a plagas	A	B	C
Cuál variedad resiste peor a plagas	A	B	C
Cuál variedad resiste mejor a enfermedades	A	B	C
Cuál variedad resiste peor a enfermedades	A	B	C

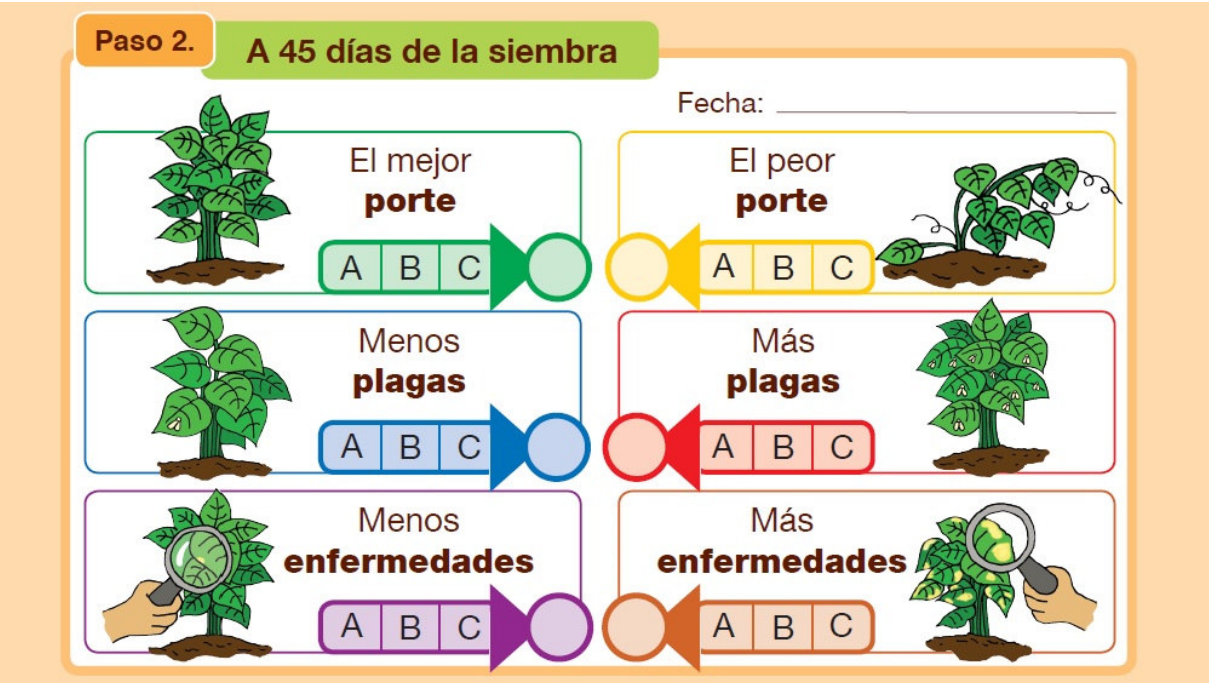


Figure 17: Previous (top) and improved design of observation card (excerpts). Improved design by: Shirley Orozco Estrada, Turrialba Costa Rica

Building a system on local facilitators

Implementing organisms, like NGOs or national extension services, should be able to identify locally respected individuals who are eligible to be local CCI facilitators. These persons must be thoroughly trained in CCI, and subsequently take responsibility for a group of maximum 25 new participants per cycle. Local facilitators would act as a connecting link between the implementers and the participants, and be responsible for training, distributing trials and reporting the registration of participants to the project implementers, collecting and passing on data, and information feedback to the participants. Local facilitators would receive a small compensation for their commitment, but being a local CCI facilitator needs to be regarded as a self-employed activity. Candidates would be incentivised by the social prestige of agricultural expertise, but would also get the privilege to act as intermediary traders for local seed innovation. After successfully having carried out the trials, farmers are told the names of the varieties they had received, and may want to obtain more seed in order to upscale production. Local facilitators would receive the 'orders' and pass them on to the project implementers. The facilitators' profit margin (dealer rebate) would depend on the number of participants and an index of usable data feedback. This would incentivise facilitators to include many members of their community, as well as to ensure sound training. Strategies need to be developed to avoid the reporting of fictitious participants, or data, in order to obtain a bigger benefit, and to avoid conflict with traditional local seed retail. Local facilitators would be free to involve as many local farmers as they wish, yet only trials successfully feeding information into ClimMob increase their financial benefit. This way, by linking both data quality and participant number to a financial incentive, it is likely to maximise the effective impact per facilitator. An individual facilitator's action area needs to be outlined clearly so as to avoid conflicts and contradicting activity between various facilitators.

Including mobile phone technology in data collection

Data collection can be carried out using participants' mobile phones. The task of data collection can be performed by local facilitators, who are likely to have personal acquaintance of the participants and know at what times to call them. Depending on spatial proximity, facilitators may also opt for collecting the observation cards from participants. The local facilitators should be equipped with the participants' telephone numbers, as well as sufficient airtime credit for this duty. Once the facilitators have compiled all available data, they may use reverse calls to the project implementers to report the data from all participants in their responsibility.

Data collection by mobile phones can increase a local facilitator's capacities in terms of participant numbers, but should not be used with first-time participants due to the importance of personal contact and informal exchange to build or enhance mutual trust between the farmer and the facilitator. This trust strengthens commitment and belief in the methodology's potential, and allows easy clarification of open questions. Farmers who have previously carried out an individual trial (this may mean a total of two cycles for participants who got involved with a group) could then move on and join the category of farmers reporting data by phone. This way, local facilitators can focus their facilitation efforts on new participants, and interaction with previously experienced participants would be reduced to the distribution of trial packages, data collection by phone, and information feedback by phone. Depending on their general level of autonomy, with experienced participants, a total number of up to 100 trials per facilitator is conceivable.

Extending geographic coverage

In order to include a higher number of farmers, beyond the area where CIALs are established, efforts in promotion are needed. Trial packages are relatively low-cost for project implementers, so the threshold to hand out trials is low, even when follow-up facilitation and data collection may be considered difficult. Registration of participants and distribution of trial packages of a region-level CCI project may happen at open access events like farmers' markets or seed fairs.

Yet, coverage could be massively enhanced if CCI trial packages were sold in agricultural shops as 'bean seed improvement sets'. In this scenario, commercial agricultural stores would play the part of local facilitators in terms of trial distribution and registration of participants, and are equally incentivised by the privilege of becoming the future dealers for the trial varieties. Interested farmers might purchase the trial packages at low cost and get a brief explanation at the store. Staff would pass on the list of registered farmers to the project implementers, who can then invite farmers to initial training events and use these telephone numbers for phone-based data collection. An explorative study is recommended to assess the potential of data feedback in these settings of entirely un-associated participants.

Cooperation with existing local structures should be enforced: When a community leader, like a village mayor, can be asked to identify potential local facilitators, promotion and training may focus on these individuals. CCI should be promoted as a development measure to be adopted by local NGOs or farmers' organisations, i.e. any organisation that works with farming population and enjoys a position from which new technologies may be distributed. Yet the strongest impact may be reached by cooperating with governmental services. Promotional efforts should be targeted at governmental extension services. While many governmental seed supply agencies focus on producing and repeatedly distributing seed of few high-yielding varieties to smallholder farmers, efforts should be directed to convincing agricultural officers of the importance of dynamic and diverse seed systems, as well as the potential of CCI of fostering seed self-reliance of rural communities. A first step towards cooperation with governmental organisations like the DICTA[9] of Honduras could consist in inviting authorities to observe a CCI project cycle and report on the benefits.

[9] *Dirección de Ciencia y Tecnología Agropecuaria:* Agency for agricultural science and technology

4 Summary and main conclusions

This study contributes to the recently emerging body of knowledge about citizen science. It is the first scientific study about crowdsourcing agronomic data with smallholder farmers, and important conclusions for the development of Crowdsourcing Crop Improvement, but also for other, future, citizen science projects with farmers can be drawn. It was documented that CCI can produce scientifically robust results and relevant output for farmers in their pursuit of improved livelihood.

As was shown, the evaluative criteria chosen by researchers and extensionists for the Honduran CCI project were well selected. Just five out of the seven criteria accounted for about 66 % of preference criteria mentioned by farmers. This means that meaningful results can be generated even by restricting the variety evaluation to a manageable, low number of criteria. Although trait preferences and priorities differ at the individual level, and, more so, due to regional differences in environment, socio-economic context and cultivation history, it was possible to construct an adequate approximate consensus for smallholder farmers from four regions of Honduras. Along the research to this study, it became clear that yield stability is more relevant than increases in yield potential, which is why CCI should focus on selecting varieties that contribute to this objective.

While controversy about whether decentral, crowdsourced, citizen science is able to comply with ‘scientific standards’ is likely to never cease, this study evidences that farmers’ observations, on the whole, are not random, but accurate, at varying levels depending on the respective trait’s ease of visual observation. Farmer observation is, thus, a reasonable scientific method. With the detected levels of accuracy and the type of ranking observation requested in CCI, moderate and realistic numbers of observations are sufficient for significant distinction of crop varieties by Bradley-Terry models. This result is encouraging new applications of citizen science with farmers, as a method of highly client-oriented research. Ease of trait observation or, alternatively, specific basic training for observation, should guide the design of crowdsourcing projects with farmers.

Because participating in CCI in the setup presented in this study requires access to land, which is predominantly held by men in many places worldwide, gender equity is not in central focus. However, women are empowered by participating in women’s research groups, and CCI represents an easy, low-threshold methodology for women to get involved in agricultural activities and research, and this way strengthen their position in the household as well as the rural society. Above all, women's and men's variety preferences seem to be equal in this study's context, which means that men's evaluations and variety selections in CCI can be expected to benefit rural women equally. This particular situation, however, may not be given in all locations, and a male majority in CCI may in fact lead to increased gender disparities elsewhere. Giving women farmers, but especially farmers' housewives, an adequate say in CCI must be an important goal in further implementations.

Farmers' engagement in citizen science was shown to be driven by rational motives, mainly by the pursuit of an improved livelihood and economic development of their community. Unlike in most other citizen science projects, fun is a negligible motive for most farmers. Yet when the possibility of improving livelihood is perceived, farmers are highly motivated to participate. Three main incentives for participation were identified: Agronomic capacity building, the inherent access to new, adapted crop varieties, and the generation of social capital. The acquisition of skills and knowledge is not only likely to improve data quality and return rate, but was seen to be the strongest driver of farmers' engagement in citizen science, as an indirect lever of agricultural development. Therefore, if possible, citizen science with farmers should include elements of capacity building relevant to cultivation, in addition to the learning that comes with participating. This way, large numbers of farmers can be motivated to participate.

Useful insights were gained about opportunities and pitfalls of upscaling CCI from locally specific experiences to a scalable, generalised model. Although promoting the methodology with donors, local NGOs and rural grass-root organisations are strategies to involve additional actors to an existing project, the key to upscaling is likely to lie in automatising the process by two adjustments. Firstly, minimising the requirements of facilitation per participant by streamlining all steps of participation to maximum simplicity and clarity, and using mobile phone technology: For example, the observation card participants use to record their trial evaluations can be designed to be more accessible for farmers with restricted literacy, too. Initial training events may convey all capacity required for participation – yet if one event is not sufficient to create an adequate level of understanding, then the requirements need to be simplified, like adapting the evaluative criteria.

Secondly, it is suggested that the crowdsourcing project be constructed around specially trained *local facilitators*, who are incentivised to work towards quantity and quality of farmer participation by economic opportunities and personal benefits. These local facilitators, ideally lead farmers from rural communities, need to be given a protocol of activities they are responsible for, including the initial training workshop for first-time participants, data collection and passing on observation data to the project implementers. This way, a crucial bottleneck of communication – between farmers in remote locations, and extensionists who need to spend resources on transportation and building trust – is avoided, and extensionists can focus on a manageable number of facilitators, who may be equipped with tablet computers, mobile phones and/or airtime credit, to facilitate communication and mutual data and information transmission.

Although subject to practical testing, massive upscaling of CCI seems feasible. Committed researchers and implementing bodies will always be key to a project's success, especially as there can be no general scheme to implementation, and CCI will always need creative and flexible local adaptation. Nevertheless, this study shows that citizen science with farmers is viable, scalable, and yields robust and meaningful results. These results may be inputs to a large variety of potential new applications of the crowdsourcing approach in agricultural and development research.

The results of this study allow the assumption that CCI has the potential to contribute to smallholder farmers' adaptation to climate change and their enhanced food security in regions of strong climate hazard. By further developing CCI as a flexible and scalable strategy, and with national or sub-national organisations taking a strong role in implementation, many farming households affected by climatic changes may get access to an array of better adapted cultivars, and are empowered to take effective adaptation decisions. In combination with the vital practice of conserving genetic diversity locally in community seed banks, overall levels of food security of rural families in times of climate change may be boosted, and climatic shocks can be mitigated. Stagnating yield levels and climate-related disasters are a common reality for resource-poor farmers in many parts of the world, while crop researchers often lack effective tools to distribute seed innovation beyond selected villages. Incentivising and promoting crowdsourced experimentation with a low capacity threshold and a wisely selected array of varieties currently seems the most promising strategy to provide a high number of farming households with the technology to meet their nutritious needs more reliably.

CCI projects need to be carried out in regions with a variety of climatic and socio-economic conditions. This way, the results, i.e. the characterisation of a variety's optimum environment, can be shared with crop researchers and extension programmes worldwide, and synergies should be expected: By connecting the trials with environmental data from sources like remote sensing or networks or low-cost sensors (cf. van Duivendijk 2015), the varieties' suitabilities for similar environments around the globe may be predicted, cultural preferences let aside. If CCI and subsequent analysis is consequently enhanced by this feature, benefits will go far beyond the limited region of implementation, and climate adaptation through seed innovation is sped up at a global level.

5 Further research recommendations

CCI was introduced in response to shortcomings of existing participatory approaches to crop variety research, including participatory variety selection (PVS). Low rates of variety adoption and field sustainability were attributed to deficient observation of varieties at important steps in the cultivation cycle. Yet with crowdsourcing data right from the citizen scientists' own farms, farmers have the chance of observing the varieties' entire development and their behaviour at different growth stages. At this moment, it is too early to assess the project's impact in terms of adoption. However, over the next years, evidence will need to be collected on whether CCI leads to increased and lasting adoption of improved varieties.

Another assumption of CCI is that it can lead to increased *in situ* agrobiodiversity. By testing a larger number of different crop varieties at many locations, farmers are enabled to identify the most suitable variety for their local environmental conditions. However, if utility differences among the tested varieties are too strong, an adverse development may take place: Different local landraces are replaced by just a single improved variety, in consequence making the landscape less diverse and more vulnerable to climatic shocks. Hence, additional research is needed on the impacts of CCI on local agrobiodiversity at the variety level.

Various recommendations presented in this study will require empirical scrutiny and practical adjustments. Particularly, this includes the use of mobile phone technology for data collection, and the kind and extent of involvement of local facilitators. How 'local' the facilitators need to be in order to work more efficiently than CCI extensionists, i.e. how many different communities and farmers they may assist, is a question that needs to be studied.

The system of local facilitators, incentivised by the privilege of trading the trial varieties, requires careful research, including questions of social marginalisation and preferentialism, gender issues, most appropriate incentives, and the potential competition with established seed trade networks. A small-scale, explorative implementation of a facilitator-based CCI could provide much insight and learning.

It was mentioned that, in massive upscaling of CCI, automated voice calls could be used to collect data from participants. Further research is needed to assess how farmers interact with such a system. For example, are farmers less likely to respond correctly to a generic voice than to a record of a familiar person? What are costs and benefits of calling and greeting a farmer in person, and then 'handing over' the call to an automated voice (this way, facilitators or extensionists may be able to call more participants in less time)?

Lastly, this study suggests that farmers' observation capacities may be enhanced by training events at the beginning of a CCI cycle. It would be useful to analyse the real costs and benefits of these activities. If benefits in terms of improvements in accuracy and data return are low, the costs and efforts for all actors might not be justified.

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I hereby declare that the present thesis has not been submitted as a part of any other examination procedure and has been independently written. All passages, including those from the internet, which were used directly or in modified form, especially those sources using text, graphs, charts or pictures, are indicated as such. I realize that an infringement of these principles which would amount to either an attempt of deception or deceit will lead to the institution of proceedings against myself.

Date Signature

7 Annex

A Interview guidelines for key informant interviews

1. Please tell me how CCI was introduced and implemented in your area:

   - Selection of participants
   - Role of field promotors
   - Cultivation of trials in groups or individual farmers
   - Who evaluated the trials
   - Who recorded the observations
   - Different stakeholders' responsibilities
   - Was anybody trained in any way?
   - What difficulties were perceived and how were they overcome?

2. How do you perceive the data quality?
3. How could the methodology be extended to include farmers who are not CIAL members?

B Guideline for women's focus group discussions

Thematic blocks:

1 Gendered domains in the farm household

2 Seed preferences

3 Experiences with CCI

1 Gendered domains in the farm household

Research interest	**Questions to the women**
Depth and kind of women's interaction with beans *(Outlining the gender domains with respect to beans)*	· What are the steps in bean cultivation? · When do you get in touch with beans? · What do you ever do with beans?
Farming system	· What does your family plant beans for (home consumption / market / other)? · How much is the area of land of your farm? · How much of your land is dedicated to beans? What do you consider to decide this? · How does your family obtain seed for sowing?
Knowledge about varieties, involvement in variety choice	· Do you know different bean varieties? · In what are they different? For example, describe some varieties with their good qualities and their problems. · Why are some varieties better, and others worse? · Do you know which varieties are planted in your farm? How is that decided? · How do you like the varieties which are planted? What don't you like?

2 Seed preferences

Research interest	Questions to women
Women's variety preferences	· Is there any other variety which you like better? *(e.g. from neighbours, past)* · Why does your family not grow that variety? · Have you ever changed the variety(ies) you grow, or ceased cultivation of any variety? · If yes, why?
Differences to husbands' preferences	· What do you think do your husbands like most about the varieties you grow? · Do your husbands like the same varieties like you? · Is there any difference between what you like and what your husbands like? · Do you ever speak about these differences?

3 Experiences with CCI

Research interest	Questions to women
Knowledge about CCI	· What is CCI? Did you see your family's CCI plot? · What do you think about your family's trial and the trial varieties? · Who participates in CCI and why · What could be the benefit of CCI? · Have you already observed any benefit?
Participation in CCI	· Did you see the observation card? Do you know what it contains? Who filled it out? · Did you talk about CCI in your family? · Did you see the seeds from the CCI trials? What do you think about them?
Opinions about CCI	· What do you think about CCI? · What can be improved? · Would you like to keep participating?

C Observation sheet used in first farmer trial evaluation activity

Outside:

Taller de Tasación EPM

Taller de Observación EPM

Muchas gracias por su participación en la Evaluacion Masiva de Variedades de Frijól!

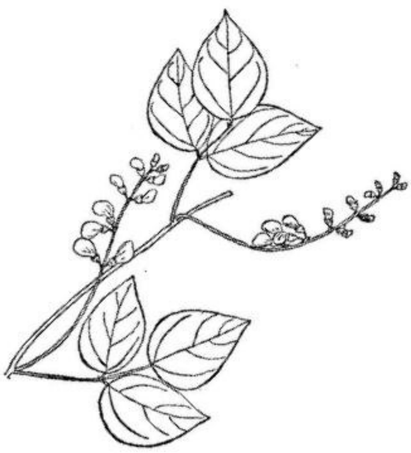
Fecha: ______________________

Nombre del participante: ______________________

De quién es el ensayo visitado: ______________________

Inside:

Por favor llene la tarjeta al lado derecho, como USTED ve la parcela presente!



Preguntas sobre las plantas *Compare las tres variedades*	**Respuesta** *Subraye solo una variedad por cada pregunta*		
Cuál variedad resistió mejor a enfermedades	A	B	C
Cuál variedad resistió peor a enfermedaes	A	B	C
Cuál variedad resistió mejor a plagas	A	B	C
Cuál variedad resisttió mejor a plagas	A	B	C
Cuál variedad tiene el mejor porte	A	B	C
Cuál variedad tiene el peor porte	A	B	C
Cuál variedad rinde mejor	A	B	C
Cuál variedad rinde peor	A	B	C

D R codes used in this study

1. Confidence intervals around random baseline of farmer observation validity (section 2.3.4.3.2) (example)

	Plant architecture	**Vigour**	**Pest resistance**	**Disease resistance**	**Mean**	**SD**
Total number of observations	26	22	13	11	-	-
Share of observations with $\tau = 0$ among all observations	54	64	56	27	51,49	12,22

Table provided for better understanding of R code.

```
# mean =mean share of observations with Kendall's tau distance=0
# among all observations on one plant trait, each weighted by the
# total number of observations on this plant trait
# sd =standard deviation within all these 72 values
# confidence intervals were calculated both for n=26 and n=11

mean <- (26*54 + 22*64 + 13*46 + 11*27)/72
sd <- 12.22
n <- 11
halfinterval <- qnorm(0.975)*sd/sqrt(n)
lower <- mean-halfinterval
upper <- mean+halfinterval

> mean
[1] 51.48611
> interval
[1] 7.221426
> lower
[1] 44.26857
> upper
[1] 58.71143
```

2. Fitting a BT model to farmers' ranking of varieties in the farmer trial observation activities (section 2.3.4.3.2) (example)

Variety.1	Variety.1	win1	win2
X	Y	19	3
X	Z	22	0
Y	Z	16	5

Table for illustration: Binomial counts of the 22 observations on 'vigour', input to the BT model

```
library("BradleyTerry2", lib.loc="~/R/win-library.1")

vigour.model <- BTm(cbind(win1,win2), Variety.1, Variety.2,
                    formula = ~ Variety.,
                    id="Variety.",
                    data = vigor.bt2.sf)
```

3. Main effects models of farmers' selections in discrete choice experiment (section 3.2.2) (example)

Name	Fraction	Yield. level	Market. level	Pest. resistance[1]	Disease. resistance[1]	Response[2]
Farmer1	1	12	600	0	0	0
Farmer1	3	12	900	0	0	0
Farmer1	6	18	600	1	0	1
Farmer1	7	18	900	1	0	0
…	…	…	…	…	…	…

[1] 0 = low level, 1 = high level
[2] 0 = reject, 1 = acceptance

Table for illustration: Excerpt of trait levels and farmers' discrete choices in stated choice experiment (data frame Factorial.data_A*)*

```
# Creating the model

model_A <- glm(Response ~
               Yield.level +
               Market.level +
               factor(Factorial.data_A$Pest.resistance) +
               factor(Factorial.data_A$Disease.resistance),
               family = binomial(link = probit),
               data=Factorial.data_A)

# Stepwise improving the model

step(model_A)
summary(model_A)

#  Validating the model

anova(model_A, test = "LRT")
```

4. Bradley-Terry tree modelling of participants' trait preferences in pairwise choice experiment (section 3.2.3.2) (example)

1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	1	-1	-1	-1	-1	1
1	1	1	1	1	-1	1	-1	1	1	1
-1	-1	-1	-1	1	1	1	-1	-1	1	1
-1	1	-1	-1	1	1	-1	-1	-1	-1	-1

Table for illustration: Table 'Paircomp.data' *(excerpt) of pairwise choices of all respondents (lines) on all 21 dilemmas (columns). 1 means preference for first trait, -1 means choice of second trait.*

```
library("psychotree", lib.loc="~/R/win-library/3.1")
labels <-  c("Yield","Market","Taste","Diseases","Pests",
           "Vigour","Architecture")

# Assigning the corresponding pairwise comparisons of two traits
# to the previously unlabelled table 'Paircomp.data'

paircomps <-    paircomp(Paircomp.data,labels = labels,
                mscale=NULL, ordered=FALSE,
                covariate = NULL)

# Adding the explanatory variables to create a final data table

observerID <- c(1:39)
age <-
     c(31,57,48,45,48,60,59,62,61,NA,28,52,14,46,49,87,40,25,31
     ,NA,49,48,41,34,40,31,35,41,34,39,41,32,35,18,35,37,54,63,
     54)
gender <-
     c("Male","Male","Male","Male","Male","Male","Male","Male",
     "Male","Male","Female","Male","Female","Male","Female","Fe
     male","Female","Female","Female","Male","Male","Female","F
     emale","Male","Male","Female","Male","Male","Male","Female
     ","Male","Female","Female","Female","Female","Female","Fem
     ale","Male","Female")
region <-
     c("Yojoa","Yojoa","Yojoa","Yojoa","Yojoa","Yojoa","Yojoa",
     "Yojoa","Yojoa","Lempira","Lempira","Lempira","Lempira","L
     empira","Intibuca","Intibuca","Intibuca","Intibuca","Intib
```

```
     uca","Intibuca","Intibuca","Yoro","Yoro","Yoro","Yoro","Yo
     ro","Yoro","Yoro","Yoro","Yoro","Yoro","Yoro","Yoro","Yojo
     a","Yojoa","Yojoa","Yojoa","Yojoa","Yojoa")
municipalality <- c("San Jose de Comayagua","San Jose de
     Comayagua","San Jose de
     Comayagua","Taulabe","Taulabe","Taulabe","Taulabe","Concep
     cion del Sur",NA,"San Andres","San Andres","San
     Andres","San Andres","San Andres","Jesus de Otoro","Jesus
     de Otoro","Jesus de Otoro","Jesus de Otoro","Jesus de
     Otoro","Jesus de Otoro","Jesus de
     Otoro","Yorito","Yorito","Yorito","Yorito","Yorito","Yorit
     o","Victoria","Victoria","Victoria","Victoria","Victoria",
     "Victoria","Concepcion del Sur","Concepcion del
     Sur","Concepcion del Sur","Concepcion del Sur","Concepcion
     del Sur","Concepcion del Sur")
household.size <-
     c(4,6,6,4,4,5,4,3,4,NA,2,8,10,5,10,2,3,10,8,NA,7,NA,NA,NA,
     NA,NA,NA,5,6,NA,NA,NA,NA,3,5,5,6,3,3)
constant.variable <-
     c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
     1,1,1,1,1,1,1,1,1,1,1)

loteria.data <-
     data.frame(observerID,age,gender,region,municipio,househol
     d.size,constant.variable,paircomps)

# Getting the overall picture, without partitions.

loteria_tree0 <-     bttree(paircomps ~ constant.variable,
                     data = loteria.data, minsize = 2,
                     ref = "Yield")
loteria_plot0 <-     plot(loteria_tree0, abbreviate=FALSE,
                     yscale=c(0.05,0.2))
summary(loteria_tree0)
itempar(loteria_tree0)

# Testing individual explanatory variables (example)

loteria_tree_region <-     bttree(paircomps ~ region,
                           data = loteria.data, minsize = 2,
                           ref = "Yield")
plot(loteria_tree_region, yscale = c(0,0.5))
summary(loteria_tree_region)
```

```
itempar(loteria_tree_region)

# Combined tree with region and municipality as explanatory
# variables

loteria_tree_region.and.municipality
     <-   bttree(paircomps ~ region + municipality,
          data = loteria.data, minsize = 2, ref = NULL)
plot(loteria_tree_region.and.municipality)
summary(loteria_tree_region.and.municipality)
itempar(loteria_tree_region.and.municipality)
```